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Effects of Shortwave Diathermy, Ultrasound, and Hot Packs on Ulnar Motor Nerve Conduction Velocity

by

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A THESIS

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The undersigned certify that they have read, and recommend to the Faculty of Graduate Studies and Research, for acceptance, a thesis entitled Effects of Shortwave Diathermy, Ultrasound and Hot Packs on Ulnar Motor Nerve Conduction Velocity submitted by Yvette D. Claveau in partial fulfilment of the requirements for the degree of Master of Science

Department of Physical Therapy.

DEDICATION

This thesis is dedicated to Marion. Thank you for your critique, sense of humour and confidence.

ABSTRACT

The effects of a 20 minute treatment of shortwave diathermy, a five minute treatment of ultrasound at an intensity of one watt per square centimeter continuous current, and a 20 minute application of hot pack on the subcutaneous tissue temperature of a 10-12 centimeter segment of the proximal antero-medial aspect of the forearm and the motor nerve conduction velocity of the ulnar nerve was examined in 18 subjects. Each subject was tested three times, using one of the modalities on each test. Only the dominant arm was used. Subcutaneous tissue temperature and motor nerve conduction velocity data were collected four times during the procedure: 1) one minute pre-treatment, 2) zero minute pre-treatment, 3) zero minute post-treatment, and 4) one minute post-treatment. A subcutaneous tissue layer measurement of the triceps and the forearm was taken on each subject. A two by three way analysis of variance with repeated measurements over two factors was used to analyze the data. The results indicated that application of shortwave diathermy and hot packs produced a significant increase in subcutaneous tissue temperature and motor nerve conduction velocity of the ulnar nerve. There was no statistically significant change in subcutaneous tissue temperature or motor nerve conduction veloctiy with ultrasound. The Pearson Product Correlation Coefficient demonstrated a statistically significant correlation between the change in subcutaneous tissue temperature and the change in motor nerve conduction velocity with hot packs only. No other statistically significant correlation was found between the change in subcutaneous tissue temperature, the change in motor nerve conduction velocity, and the skinfold thickness layer.

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Lastly, I would like to thank my family for their care, love, and support.

Table of Contents

LIST OF TABLES

LIST OF FIGURES OR ILLUSTRATIONS

A. CHAPTER I - THE PROBLEM

Motor nerve conduction velocity has been shown to increase as tissue temperature is raised[1 9]. Heating modalities such as shortwave diathermy, ultrasound, and hot packs are frequently used as part of physical therapy treatments, yet little is known concerning the specific physiological effects of each modality on motor conduction velocity[10]. An important factor influencing change of motor nerve conduction velocity is variations in the temperature in the tissue surrounding the nerve[1 8 9]. As each modality has different depths of penetration and different selective tissue heating, it might be postulated that each modality will produce different heating effects in the tissue surrounding the nerve[11].

Shortwave diathermy is known to heat predominately tissue of higher fluid content such as muscle and blood vessels[10 11]. As well, it is not easily transmitted through fatty tissue[11].

Ultrasound is easily transmitted through fatty tissue[12]. Reflection of ultrasound occurs at bone-soft tissue interface. Therefore, additional heating effects will occur at the bone-soft tissue interface due to the reflection of the ultrasound[13]. In addition to the heating effect, ultrasound has been reported to have a mechanical or vibromassage effect on tissue[4].

Hot packs are a form of conductive heat and, as such, have only a superficial heating effect[11]. Lehmann, et al.[14] demonstrated that hot packs produce an increase in tissue temperature to a depth of three centimeters.

Figures 1, 2, 3 and 4 demonstrate changes in tissue temperature at various depths with application of either shortave diathermy, ultrasound, or hot packs[13 15].

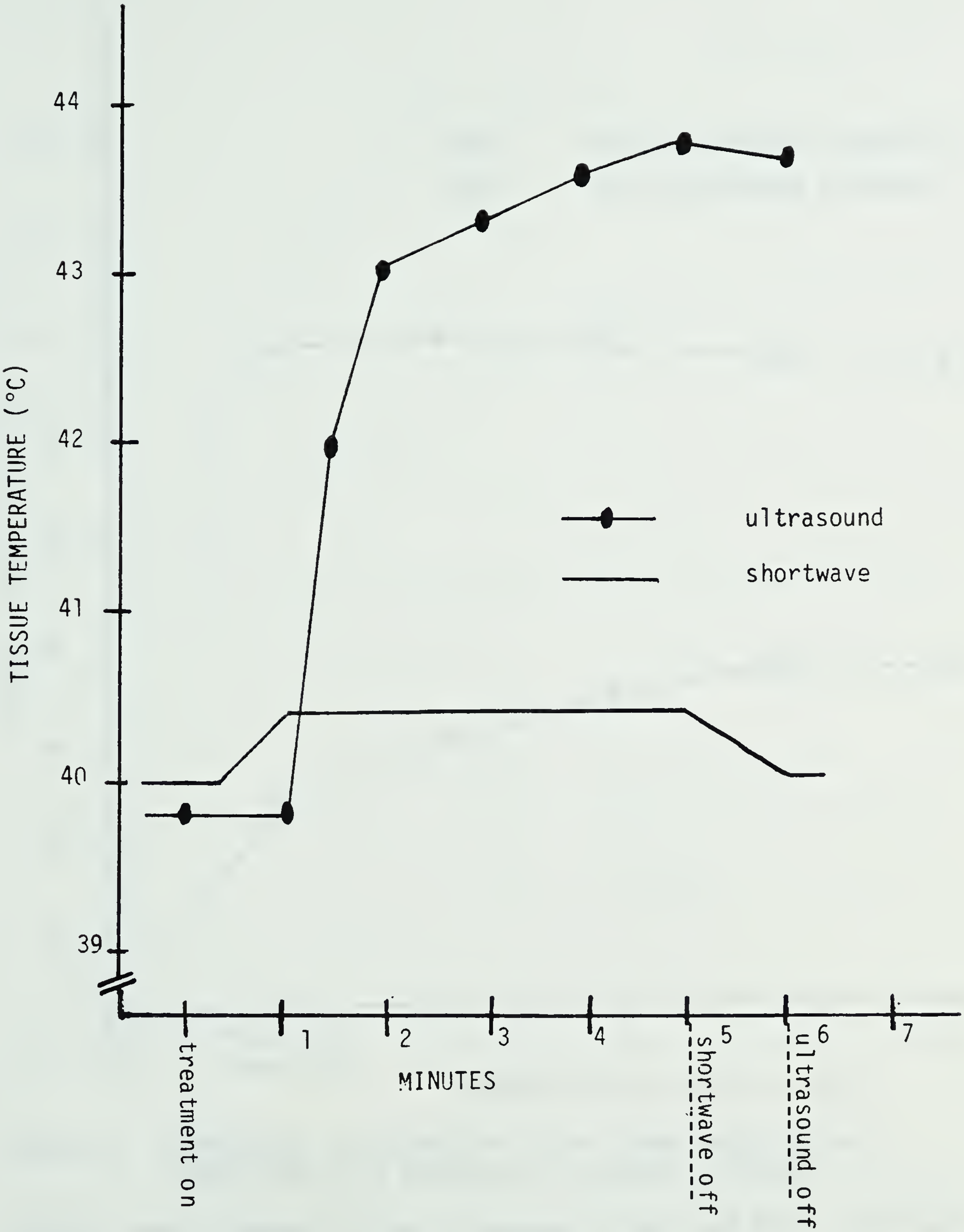

FIGURE 1: CHANGE IN TEMPERATURE INSIDE THE HIP JOINT FOLLOWING THE APPLICATION OF SHORTWAVE DIATHERMY AND ULTRASOUND

Adapted from: Lehmann JT, ed: Therapeutic Heat and Cold. Williams and Wilkins. Baltimore/ London, 1982, pg. 495.

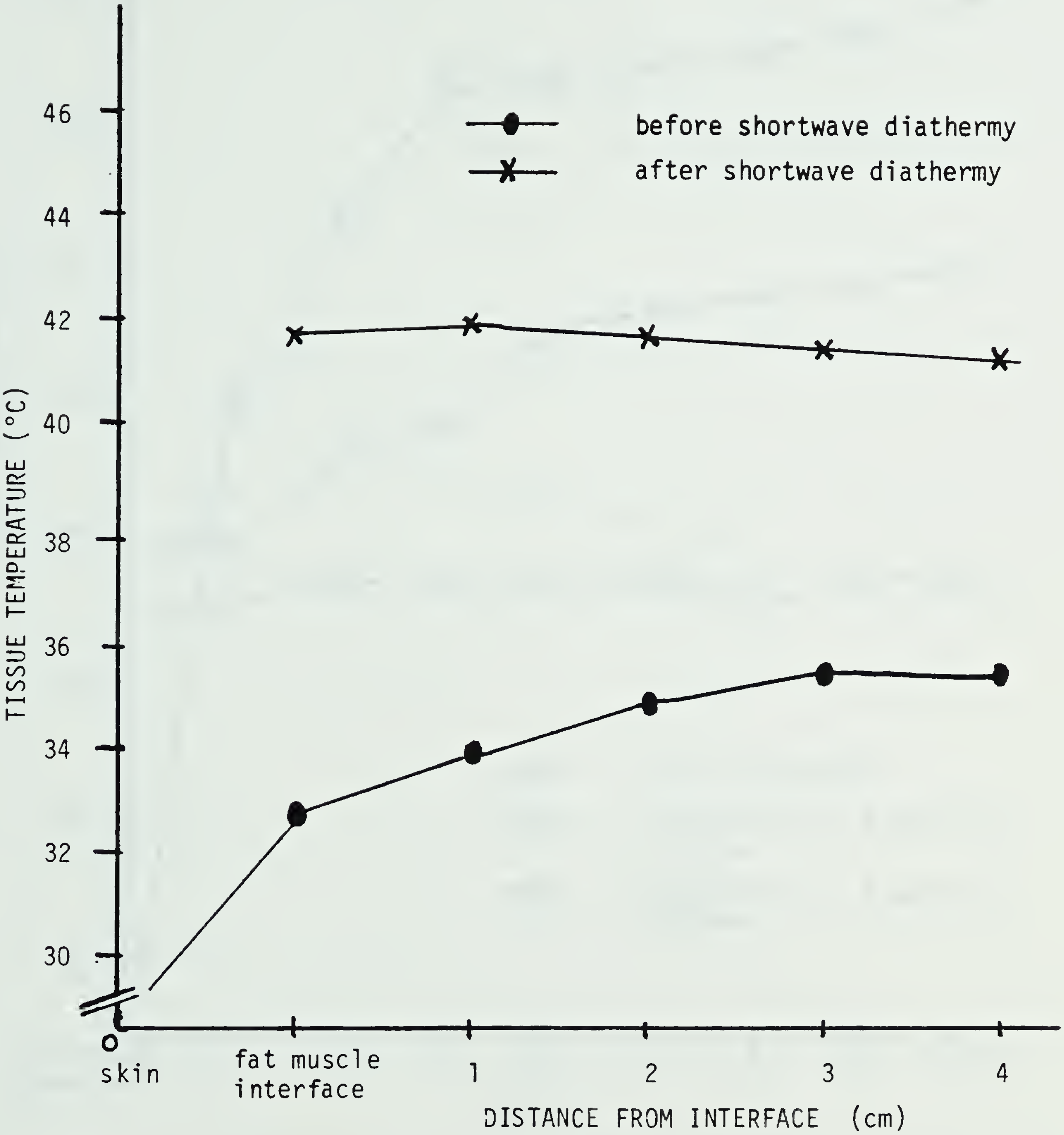

FIGURE 2: TEMPERATURE DISTRIBUTION IN THE HUMAN THIGH AT THE COMPLETION OF 20 MINUTES OF SHORTWAVE DIATHERMY

Adapted from: Lehmann JT, ed: Therapeutic Heat and Cold. Williams and Wilkins. Baltimore/ London, 1982, pg. 455.

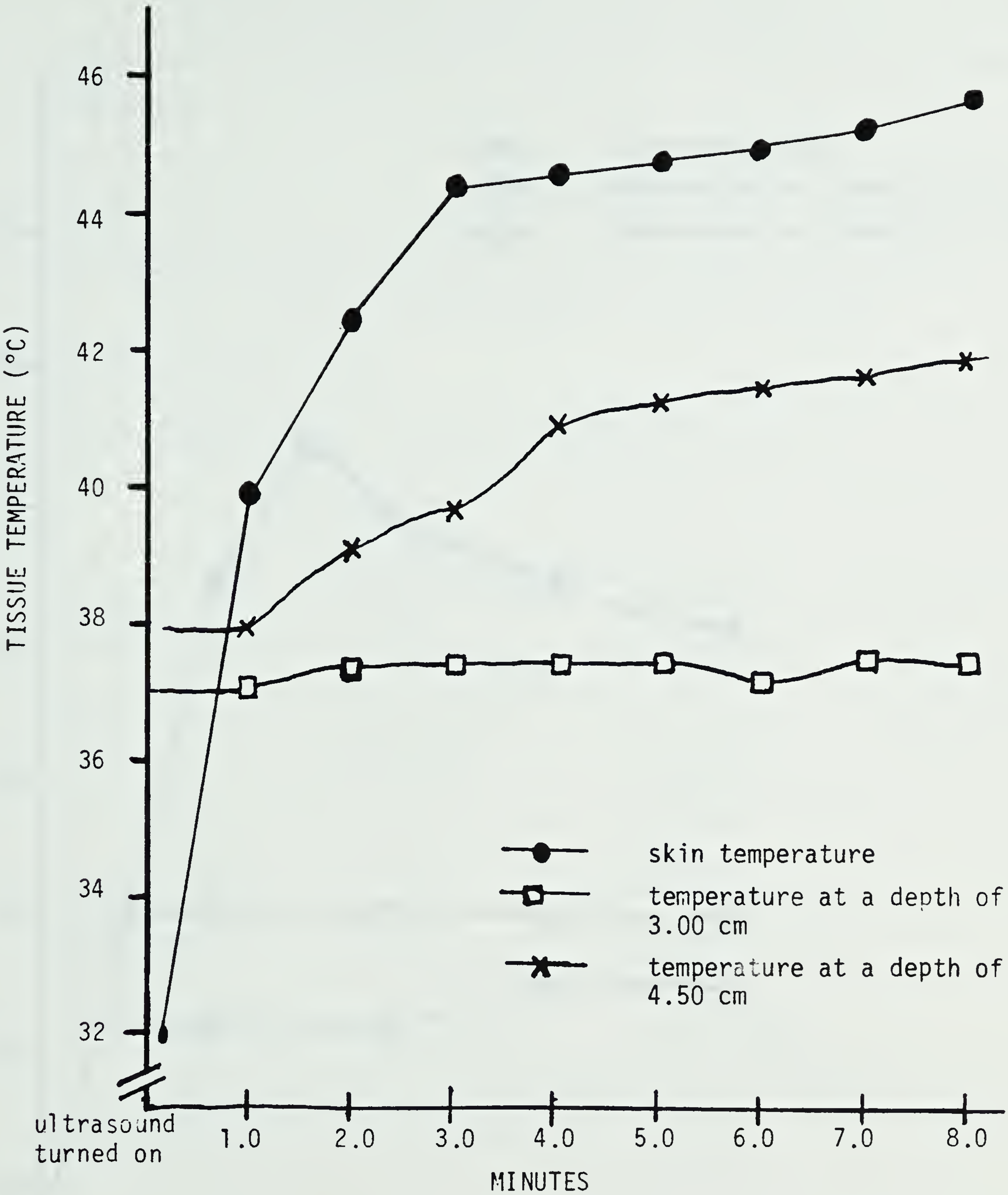

FIGURE 3: TISSUE TEMPERATURE CHANGE AT SKIN SURFACE 3.00 cm AND 4.5 cm DURING THE APPLICATION OF ULTRASOUND (INTENSITY: 1 wtt/cm^2; MINERAL OIL COUPLE AT 24°C)

Adapted from: Lehmann JT, Delateur BJ, Selverman DH: Selective Heating Effects of Ultrasound in Human Beings. Arch Phys Med Rehabil 47:333, 1966.

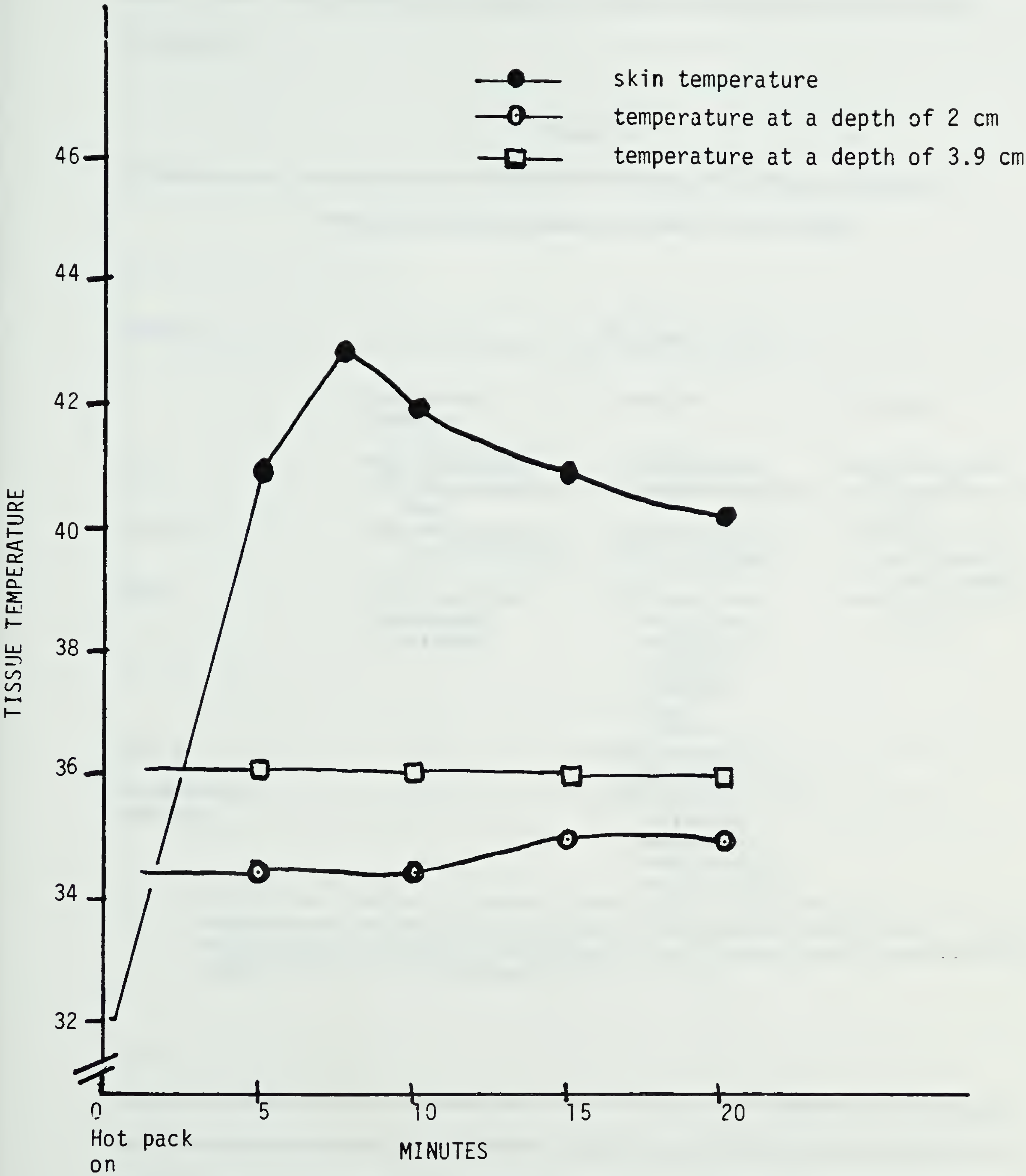

FIGURE 4: TISSUE TEMPERATURE CHANGE AT SKIN SURFACE, 2.0 and 3.9 cm DURING 20 MINUTES APPLICATION OF HOT PACK

Adapted from: Lehmann JT, ed: Therapeutic Heat and Cold. Williams and Wilkins. Baltimore/ London, 1982, pg. 430.

Tissue may either absorb or transmit heat differently depending on the modality used. Table 1 is a summary of the reaction of various tissues to the three different modalities[11].

TABLE 1

Comparison of the absorption and the transmission of shortwave diathermy, ultrasound, and hot packs in different body tissue.

Tissue	Modalities: Shortwave Diathermy	Ultrasound	Hot Packs
Fat	-high absorption -poor dissipation of heat	-low absorption, high tranmission	-high absorption -poor dissipation of heat
Muscle	-high absorption, low transmission	-poor absorption -high transmission	-absorption if heat penetrates to muscle depth
Bone	-poor absorption -impede heat transfer	-high absorption may reflect ultrasound waves at bone-soft tissue interface	-does not penetrate to bone
Nerve	?	-high absorption, low transmission	?
Bone-muscle interface	?	-reflection of ultrasound causes local increase heat in adjacent tissue	?

Adapted from: Wadsworth H, Chanmugan A: Electrophysical Agents in Physiotherapy Therapeutics and Diagnostic Use. Science Press. Manichville NSW Australia, 1980. (? = unknown)

Because fatty tissue has a high absorption rate with shortwave diathermy and hot packs, and a low absorption rate with ultrasound, it might be presumed this difference in the absorption rate between the three modalities will have different effects on the heating of tissue lying below the fat.

To date, the question of the effects of shortwave diathermy, ultrasound, and hot packs on motor nerve conduction velocity has not been fully answered. Physical therapists utilize these modalities over peripheral nerves and nerve roots without knowing the physiological effects these modalities may have on the underlying nervous tissue. The frequency with which these modalities are used, for example, in the treatment of low back pain, makes it essential to understand their physiological effects.

RESEARCH HYPOTHESES

1. H_1: There is an increase in motor nerve conduction velocity following the application of shortwave diathermy, ultrasound or hot packs.
2. H_2: There is an increase in subcutaneous tissue temperature following application of shortwave diathermy, ultrasound or hot packs.
3. H_3: There is a significant correlation between the observed changes in motor nerve conduction velocity and the observed changes in subcutaneous tissue temperature following treatment with each of the three modalities.

OBJECTIVES

The objectives of the present investigation are:

1. Compare the effects of shortwave diathermy, ultrasound, and hot packs given at therapeutic dosage and applied in a manner consistent with procedures used clinically on: 1) the motor conduction velocity of the ulnar nerve, and 2) the local subcutaneous tissue temperature.
2. Examine the correlation between any observed changes in motor nerve conduction velocity and observed changes in tissue temperature.

OPERATIONAL DEFINITIONS

1. Therapeutic shortwave diathermy is a form of convective heat, utilizing an electromagnetic radio frequency of 27.12 megahertz with a wavelength of 11.06 meters. Monode inductothermy consists of a flat rigid cell encased in a perspex cover. Tissue heating occurs as a result of electromagnetic radiation producing an oscillation of the molecules within the field, and thereby heating the tissue[11 15].

2. Therapeutic ultrasound is a form of mechanical energy utilizing an acoustic vibration with a frequency of 870 kilohertz and an intensity of one watt per square centimeter. Tissue heating occurs as a result of longitudinal waves producing a vibration of particles within the acoustic field. It is the mechanical friction between the particles that produces heat[11 15].
3. Hot packs provide a form of conduction heat, passing from the warmer pack to the cooler tissue with which it is in contact. A hot pack contains silica gel and is covered by strong cloth. The silica gel is capable of absorbing many times its own volume of water and, when heated, to give off thirty to forty minutes of moist heat[11].

DELIMITATIONS

1. Only the ulnar nerve of the dominant arm was tested[16].
2. The age range of the subjects was from 18 to 45 years. Both female and male subjects were examined[16].
3. All subjects fell on or below the 80 percentile range for the minimum triceps skinfold thickness indicating obesity, as defined by Mayer[18]. As the subcutaneous fat layer is a critical factor when considering the selective tissue heating produced by shortwave diathermy, ultrasound, and hot packs, the delimitation as noted was necessary [11].

LIMITATIONS

1. As there are no standards for the minimum skinfold thickness indicating obesity in the forearm, that of the triceps was used, as it is the closest area having a standard[17 18].
2. The temperature probe was inserted into the subcutaneous fat layer. Its precise depth was not measured because the probe was inserted diagonally.
3. The consistency in selection of the same point of upward deflection of the baseline for the nerve conduction velocity determination was limited by the ability

of the investigator to consistently detect this point of deflection. See description of the reliability test, Appendix C.

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B. CHAPTER II - REVIEW OF THE LITERATURE

Shortwave diathermy, ultrasound, and hot packs each have a unique tissue heating effect[1,2]. As a result, evaluation of each modality is essential to determine the selective effect each modality may have on conduction velocity of a motor nerve.

SHORTWAVE DIATHERMY

Inductothermy is a method of shortwave diathermy in which an electromagnetic field is set up around the loops of a coil through which a current is passing. The electromagnetic field is more concentrated near the conductor and will heat the more superficial tissue[1]. The production of heat is brought about by the friction of the tissue particles produced by the oscillation of the currents[1].

Inductive shortwave diathermy selectively heats tissue with the highest vascular content (i.e., muscle) and the lowest electrical impedience before heating tissue with a lower vascular content[3]. The greatest increase of tissue heat occurs in the area of the greatest current density[3].

The depth of penetration of heat is inversely proportional to the thickness of the subcutaneous fat layer[4,5]. Lehmann, et al[4] found an increase in tissue temperature at a depth of 3.89 centimeters following a 20 minute application of shortwave diathermy.

Literature concerning the effects of shortwave diathermy on motor nerve conduction velocity is limited. Currier[6] studied the effects of reflex heating of the peroneal nerve by a 20 minute drum application of shortwave diathermy to the lumbosacral area. Direct heating of the lumbosacral area produced an increase in skin temperature to 45.5 degrees Celsius, whereas the indirect heating of the skin over the peroneal nerve in the leg produced an increase in temperature to 30.54 degrees Celsius. As a result of this indirect heating, there was a small increase of 0.24 degrees Celsius in the skin temperature over the peroneal nerve and a non-statistically significant increase in motor nerve conduction velocity. The author postulated that the reason for such a small increase in motor nerve conduction velocity was that the reaction of increased tissue heat was smaller with indirect heating than the reaction to direct heating. As there was only a minor heating of the peroneal nerve by this method, this minor increase in temperature of the skin over the peroneal nerve accounts for the non-statistically significant rise in the

conduction velocity of the peroneal nerve.

Abramson, et al.[7] investigated the effects of shortwave diathermy (conductive) on motor nerve conduction velocity by placing one air spaced plate electrode over the shoulder and arm and the other over the wrist and hand. In addition, a six inch segment of the forearm was placed in a plethysmograph at different water temperatures: 34 and four degrees Celsius. In this manner, it was possible to compare the effects of shortwave diathermy on motor nerve conduction velocity when the forearm was warmed or cooled. Shortwave diathermy given for 25 minutes with a water temperature of four degrees Celcius produced a much greater increase in skin, subcutaneous tissue and muscle temperature as well as an increase in motor nerve conduction velocity of both the ulnar and median nerves than did the same procedure at 34 degrees Celsius. Two possible explanations were given. Firstly, the greater rise in tissue temperature and motor nerve conduction velocity observed at lower bath temperature may have been due to the ineffective removal of heat as a result of the vasoconstriction of the blood vessels caused by the cold water. A second possibility was these subjects were able to tolerate a greater degrees of shortwave diathermy without experiencing pain than those who had the higher water temperature. The authors concluded that an increase in tissue temperature by the above method could cause an increase in motor nerve conduction velocity of the ulnar and median nerves.

ULTRASOUND

Griffen[8] has stated four possibilities that may occur when ultrasound is applied to tissue. It may be absorbed, transmitted, reflected, or refracted. Absorption is dependent mainly on the protein content of the tissue. There is an inverse relationship between absorption and penetration in any given tissue. Nervous tissue is second only to bone in its capacity to absorb ultrasound. Peripheral nerves absorb twice as much ultrasound as skeletal muscle, and skeletal muscle absorbs more ultrasound than fat[1]. As it is the absorption of ultrasound that produces heat, it can be seen that bone is selectively heated most, then nervous tissue, whereas ultrasound will have a relatively low heating effect on fat[8].

The penetration of ultrasound is dependent upon the frequency used. The lower the frequency, the greater the depth of penetration[8]. For example, at a frequency of 90 kilohertz, 50 percent of the ultrasound energy will penetrate to a depth of ten centimeters, whereas, when ultrasound is applied over the same site, given at a frequency of one megacycle, 50 percent of the ultrasonic energy will penetrate to a depth of five centimeters[8].

The net increase in temperature brought about by ultrasound is dependent on the intensity, the area exposed, and the duration of the treatment. The higher the intensity, the greater is the heat production[3]. Lehmann[3] suggested that an area between two to five square inches (12.9 to 32.3 square centimeters) should be treated at one time. He reasoned that by moving the ultrasound head within this area, a uniform heating of the area would result. Also, if the size of the area is increased, then an increase in tissue temperature could not be expected as the heat was dissipated from the exposed area faster than it is put into it[3].

Oakley[10] suggested that if the area to be treated is larger than one and one half times the transducer head, the site should be divided into sections, each about one and one half the size of the transducer head and each section treated individually. By doing this, a uniform treatment over the area is ensured as well as prevention of concentration of peak intensities. These principles must be taken into consideration when reviewing the literature concerning the effects of ultrasound on motor nerve conduction velocity.

Zankel[11] studied the effects of ultrasound using two different methods. First, the ulnar nerve at the elbow was sonated for five minutes, and motor nerve conduction velocity from the axilla to the wrist was measured. In the second procedure, ultrasound was applied at different intensities and various durations to the ulnar nerve along its course in the forearm, and motor nerve conduction velocity was measured from the elbow to the wrist. In both procedures, only skin temperature was recorded. Procedure one did not produce a change in conduction velocity of the ulnar nerve at either one or two watts per square centimeter. In procedure two, the different intensities and duration (i.e., one watt per square centimeter for five minutes, and ten minutes, as well as two watts per square centimeter for five minutes) produced a decrease in motor nerve conduction velocity of the ulnar nerve. There was no statistically significant change in skin

temperature after the application of the ultrasound in either procedure. Despite this fact, the author concluded that the decrease seen in motor nerve conduction velocity of the ulnar nerve could be explained by some effect of ultrasound other than heat production. He felt that this decrease in motor nerve conduction velocity may have been due to a change in the rate of exchange of transmembranal electrolytes caused by the stirring or micromassage of the ultrasound. Zankel did not address the possibility that the area of exposure might have been too large with respect to the time duration to allow for effective tissue heating. Certainly, the area exposed was much greater than that suggested by Lehmann[3] or Oakley[10]. The immediate cooling effect of the ultrasonic gel was another factor not considered[8].

Farmer[12] studied the effects of ultrasound at a frequency of 87 megahertz at various intensities, (0.5, 1.5, two, and three watts per square centimeter) by sonating the ulnar nerve from the elbow to the wrist for five minutes. Changes in tissue temperature were not recorded. Farmer reported an increase in motor nerve conduction velocity at 0.5 and three watts per square centimeter and a decrease in motor nerve conduction velocity at one, 1.5, and two watts per square centimeter. Farmer reasoned that the mechanical effects overpowered the thermal effects of ultrasound at one, 1.5 and two watts per squared centimeter resulting in a decrease in motor nerve conduction velocity, whereas the thermal effects at 0.5 and three watts per square centimeter produced an increase in the motor nerve conduction velocity of the ulnar nerve.

Madsen and Gersten[13] demonstrated the importance of the relationship between ultrasound intensity, area exposed and duration of exposure. The frequency used in the study was one megahertz for each of two ultrasound generators, one having a sound head area of seven square centimeters, the other having a sound area of 12 square centimeters. The area exposed to ultrasound was the ulnar nerve from the elbow to the wrist for five minutes. This area was far greater than that suggested by Lehmann[3] or Oakley[10].

Application of ultrasound with a crystal head size of 12 square centimeters at an intensity of 0.88 and 1.28 watts pers square centimeter produced a statistically significant decrease in motor nerve conduction velocity of the ulnar nerve, while 1.92 watts per square centimeter produced a 0.5 degrees Celsius increase in tissue

temperature and an increase in motor nerve conduction velocity of the ulnar nerve. Madsen et al. also compared the different tissue temperature changes produced by both ultrasound generators used at various intensities. He reported a consistently greater increase in tissue temperature with the larger sound head at any given intensity. When the authors decreased the area covered by the sound head by half, both the temperature rise in the subcutaneous tissue and the motor nerve conduction velocity of the ulnar nerve doubled. Giving a mock ultrasound application (i.e., no emission of energy) resulted in a decrease in both tissue temperature and motor nerve conduction velocity of the ulnar nerve. Although the authors did not give a reason, it is possible that the cooling effect of the coupling agent was responsible for the decrease seen in the motor nerve conduction velocity[8].

Esmat[14], using the same procedure of sonating the ulnar nerve in the forearm as described in the prevous studies, reported intensities of 0.5 and one watt per square centimeter to be the most effective in producing an increase in motor nerve conduction velocity of the ulnar nerve. At an intensity of two watts per square centimeter, no significant increase in ulnar nerve conduction velocity was observed. However, when the ultrasound was given in a water bath at a temperature between 33 and 35 degrees Celsius there was a decrease in conduction velocity. The author did not discuss any possibilities that might explain this finding.

From the above articles, it can be seen that disagreement exists in the literature regarding the effects of ultrasound on motor nerve conduction velocity. Three studies [11 12 13] reported a decrease at lower ultrasound intensities, whereas one study [14] reported an increase at similar levels.

HOT PACKS

Hot packs do not have a selective tissue heating effect. Tissue heating is produced by a conductive heat transfer from the hot pack to the cooler underlying skin[1]. Therefore, hot packs perdominantly heat the superficial tissue rather than the deep tissue. Hot packs are capable of producing an increase of five degrees Celsius in the temperature of the skin beneath the hot pack[15]. Lehmann, et al.[15] demonstrated that hot packs are capable of producing an increase in tissue temperature to a depth of three centimeters.

However, the authors demonstrated a slight increase of two degrees Celsius in tissue temperature at a depth of two centimeters after a twenty minute application of hot packs[15].

Information on the effects of hot pack on motor nerve conduction velocity is scant. Zankel[11] reported that hot packs applied to the ulnar nerve region at the elbow for thirty minutes produced an increase in skin temperature of 9.5 degrees Farenheit (12.5 degrees Celsius) and a slight rise in motor nerve conduction velocity of the ulnar nerve. It is the large myelinated type A fibers that are the "motor nerve" part of a peripheral nerve. It is from these large myelinated type A fibers that the motor nerve cnduction velocity is tested[17].

NERVE CONDUCTION VELOCITY

The range of normal motor nerve conduction velocity of the ulnar nerve is from 46 to 75 meters per second with the mean of 59.8 meters per second[16 17]. It is the large myelinated type A fibers that are the "motor nerve" part of a peripheral nerve. It is from these large myelinated type A fibers that the motor nerve conduction velocity is tested.[17]

In the adult, age has no effect on motor nerve conduction velocity until the age of 60 years. After the age of 60 years there is a slight decrease in the conduction velocity of motor nerves[18 19]. LaFratta, et al[19] believe that this decrease in motor nerve conduction velocity has no clinical significance.

NEUROPHYSIOLOGICAL MECHANISM OF NERVE CONDUCTION

Conduction velocity is the distance an electrical impulse travels along a nerve fiber per unit of time [20]. A peripheral nerve is made up of many thousands of nerve fibers, of which there are three basic types [20 21]. Type A nerve fibers are the largest in diameter (12-22 millimicrons) and the fastest in conduction (30-120 meters per second). They are myelinated and are somatic afferent and efferent nerve fibers. Type B nerve fibers are smaller (six - 12 millimicrons) and slower (30-60 meters per second) and are also myelinated. These fibers are efferent preganglionic fibers of the autonomic nervous system. Type C are unmyelinated fibers that are smaller (one - 0.1 millimicrons) and slower (0.5 - 30 meters per second) and are associated with pain sensation[20].

In the resting state, the nerve fiber is charged; that is there is a difference in the electrical potential between the interstitial fluid outside the nerve fiber and the intracellular fluid inside the nerve fiber[20]. This resting membrane potential is usually between -70 and -90 millivolts and is generated by the sodium potassium pump. This ionic pump maintains a high concentration of sodium and chloride ions in the interstitial fluid outside the nerve fiber and a high concentration of potassium ions in the intracellular fluid within the nerve fiber. The resting membrane is relatively impermeable to sodium ions; therefore there is very little leakage of sodium into the nerve fiber[23]. Potassium ions duffuse through the nerve fiber membranes more easily, and tend to leak out of the nerve fiber until an equilibrium is reached when the inside of the nerve fiber reaches an electrically negative potential relative to the interstitial fluid (-70 to -90 millivolts). When an electrical stimulus of sufficient intensity stimulates a nerve fiber, it produces an action potential which is then self propagating[20 21]. The action potentional is characterized by the following sequence of specific events: depolarization of the nerve fiber membranes; change of permeability of the nerve fiber membrane resulting in an influx of sodium ions into the intracellular space; a momentary reversal of the resting membrane potential; inactivation of the mechanism responsible for the increase in permeability of the membrane to sodium; and, an increase of permeability of the nerve fiber membrane to potassium which results in an efflux of potassium ions out of the nerve fiber returning the membrane potential to its resting state[20 21 22]. Depolarization of the nerve fiber is best seen when a sub-threshold stimulus (a stimulus that is not strong enough to produce an action potential) is applied to a nerve fiber. A weak sub-threshold stimulus applied to the nerve fiber causes a redistribution of ions across the nerve fiber membrane which reduces the membrane potential. If the stimulus strength is increased, this redistribution of ions across the nerve fiber membrane is increased and, if the threshold level is reached, an action potential develops explosively and is thereafter independent of the stimulus[21]. Once the action potential is initiated, the membrane at that point becomes freely permeable to sodium ions allowing an influx of sodium ions into the nerve fiber at that particular site. As the result of the sodium ion influx, the membrane potential is reversed (to about +40 millivolts). Inactivation of the sodium influx is brought about by a decrease in sodium conductance. Even while inactivation of sodium ions is occurring, there is an efflux of potassium ions out of the

nerve fiber. This potassium ion efflux helps to restore the membrane back to its original resting state[21]. The self propagation of an action potential occurs by a process referred to as local circuit propagation[21]. Local circuit propagation is brought about by a potential difference between two adjacent regions of the nerve fiber. At one site (where the action potential is occurring), the membrane potential is near the sodium equilibrium potential (around +40 millivolts) and adjacent to this site, the membrane potential is near the potassium equilibrium potential (around -80 millivolts). Thus, there is a potential difference between these two adjacent regions. As a result of this potential difference, a local circuit current flows from the active region through the intracellular region to the inactive region producing a decrease in the membrane potential at the inactive region. When the membrane potential is decreased to threshold level, the permeability to sodium increases rapidly and an action potential occurs. In this way, local circuit currents produced by sodium influx and potassium efflux at an "active" region stimulates the adjacent "inactive" regions which then become "active" and an action potential is propagated along the nerve[21].

This basic summary of the neurophysiological mechanism of nerve conduction is helpful in understanding the review of the literature on how heat causes an increase in nerve conduction. Hodgkin, Huxley and Katz[23] found that a rise of 16 degrees Celsius in the squid axon resulted in a six-fold increase in the rate at which the ionic currents changed. This increase in temperature predominately increased the rate of efflux of the potassium and, to a lesser extent, the rate of the influx of sodium ions. In an earlier study, Hodgkin and Katz[24] found that temperatures between three and 20 degrees Celsius had little effect on the resting membrane potential of the squid axon. However, temperatures above 20 degrees Celsius reduced the resting potential, and temperatures below 3 degrees Celsius resulted in a slowing of the action potential particularly of the declining phase of the action potential. That is, below 3 degrees Celsius, it took longer for the potassium efflux to occur. The authors postulated that a rise in temperature might affect the permeability of sodium ions. They believed that the transfer of sodium through the cell membrane was governed by a special process involving a transient reaction with the membrane molecules and that this transient reaction had a higher temperature coefficient than the migration of potassium or chloride ions through the nerve membrane. Work

done by Gasser[25], and Schoepfle and Erlanger[26], agreed with the above findings of Hodgkin, Huxley and Katz. Gasser[25] compared the rate of change of the potential in each part of the action potential in frog nerve at 24 and 12 degrees Celsius. He found that at the lower temperature (12 degrees Celsius), there was a decrease in the rate of change of the action potential. He postulated that the change in temperature might affect the viscosity of the axon cytoplasm. An increase in viscosity (caused by a lowering of temperature) would interfere with the development of the action potential and would prolong the recovery process of the axon back to its resting potential. Schoepfle,et al.[26] found that cooling the nerve to between eight and nine degrees Celsius resulted in a prolongation of the descent part of the action potential and consequently increased the area of the action potential. They also found that when the nerve was cooled, there was a slight increase in the time it took for the appearance of the action potential to begin after the stimulus was given.

In summary, it seems that heating nerves results in an increase in nerve conduction velocity by one or a combination of the following:

1. Heat increases the sodium influx and the potassium efflux.
2. Heat increases the nerve membrane permeability to the migration of sodium ions.
3. Heat decreases the viscosity of the axon cytoplasm and therefore movement of ions within this cytoplasm is easier.
4. Heat lowers the resting membrane potential of the nerve fiber at higher temperatures.

CONCLUSION

Despite the heat effects produced by shortwave diathermy, ultrasound, and hot packs , these modalities do not unconditionally cause an increase in motor nerve conduction velocity. The effect of different methods of application on the penetration of heat, and rise in temperature are two of the major variables to be considered. The duration of exposure and the tissue being heated must also be considered. The absorption coefficient of different tissues vary with the modality used. For example, the absorption coefficient of muscle is high when using shortwave diathermy and low when using ultrasound. The subcutaneous fat layer has a high resistance to the transmission of shortwave diathermy through to the deeper underlying tissue; whereas there is little

resistance occurring to the transmission of the ultrasound waves in fat tissue, allowing for easy transmission of the ultrasound through to the deeper tissue[1 2 3]. It is evident that in comparing the effects of shortwave diathermy, ultrasound, and hot packs on motor nerve conduction velocity, the thickness of the subcutaneous fat layer is of importance. It is for this reason that the subcutaneous skin fold thickness was measured.

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C. CHAPTER III - METHODS AND PROCEDURES

EXPERIMENTAL SUBJECTS AND EQUIPMENT

Subjects

Eighteen informed subjects were examined during repeated testing in six different treatment sequences as shown below. [1] These six treatment sequences constituted all possible sequences of applying the three treatment modalities to the subjects in this experiment. By using these six different treatment sequences, control for any treatment effect and treatment order effect was achieved. Table 2 demonstrates the treatment sequence to which each subject was assigned. The method of repeated measurement was chosen to help control for the individual differences[1]. The age range of the subjects was from 18 to 45 years[2]. This age range was chosen to eliminate age as a factor affecting motor nerve conduction velocities. It has been reported there is a decrease in motor nerve conduction velocity after the age of 60 years[2].

A 10-12 centimeter segment of the anteromedial aspect of the forearm of the dominant arm of each subject was tested[3]. There is controversy in the literature as to whether there is a difference in motor nerve conduction velocity between the dominant and the non-dominant arm[2 3]. By testing only the dominant arm, any variation of motor nerve conduction velocity between the dominant and the non-dominant arm that might occur was excluded.

A skinfold measurement of the triceps as described by Mayer[4] and Larson[5] was taken. Only those persons tested who fell within the 80 percentile range of minimum triceps skinfold thickness indicating obesity were accepted into the study. See Table 3 for the minimum triceps skinfold thickness indicating obesity for the age range of 18 to 45 years[4].

All subjects were questioned regarding any history of upper or lower motor neuron disease, history of trauma to the ulnar nerve resulting in neuropraxia, axontmesis

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[1]Sequence 1 - shortwave diathermy, ultrasound, hot pack
Sequence 2 - shortwave diathermy, hot pack, ultrasound
Sequence 3 - ultrasound, shortwave diathermy, hot pack
Sequence 4 - ultrasound, hot pack, shortwave diathermy
Sequence 5 - hot pack, ultrasound, shortwave diathermy
Sequence 6 - hot pack, shortwave diathermy, ultrasound

or neurotmesis, history of fracture or dislocation of the elbow of the dominant arm or history of peripheral vascular disease[6]. In addition, all persons were screened for diabetes and metal implants before being accepted into the study[7]. (see appendix A for Questionnaire for Screening Potential Subjects). All subjects were given an information sheet and were asked to sign a consent form (see appendix A).

As variation of room temperature may have an effect on motor nerve conduction velocity, the temperature of the laboratory was kept constant at 25 degrees Celsius, plus or minus 2 degrees.

Table 2

Assignment of Treatment Sequences to Subjects

Subject Number	Treatment Sequence
1	1
2	2
3	3
4	4
5	5
6	6
7	1
8	2
9	3
10	4
11	5
12	6
13	1
14	2
15	3
16	4
17	5
18	6

Table 3

Obesity Standards

Minimum triceps skinfold thickness indicating obesity (millimeters)

AGE (Years)	MALES	FEMALES
18	15	27
19	15	27
20	16	28
21	17	28
22	18	28
23	18	28
24	19	28
25	20	29
26	20	29
27	21	29
28	22	29
29	22	29
30-50	23	30

Reproduced from: Mayer J: Overweight: Causes, Costs and Control. Prentice-Hall Inc., Englewood Cliffs, New Jersey, 1968.

Position

All subjects were tested in a supine position with the dominant arm in approximately 60 degrees of abduction; 70 degrees of external rotation; and, 20 degrees of horizontal adduction of the shoulder. This position of the shoulder was chosen so as not to restrict blood flow to the arm. The elbow was flexed to approximately 90 degrees and the forearm fully supinated[3 8]. This position was chosen in order to position the ulnar nerve laterally and uppermost and therefore make it easily accessible. The arm was stabilized in this position by pillows.

Figure 5

Position of the Subject During Experimental Procedure

Apparatus

1. Shortwave Diathermy

A Siemens 708 ultratherm with a frequency of 27.12 megahertz was used. An inductothermy monode with a diameter of nine centimeters was connected to the Siemens unit. The monode was placed three centimeters above the anteromedial aspect of the forearm, and centered directly over the inserted needle probe. The reason for this positioning was that inductothermy has a ring-shape heating pattern, heating the periphery more than the center of the ring[11]. Therefore, by placing the center of the monode over the needle probe, selective heating of the needle probe was kept at a minimum. The duration of the shortwave diathermy treatment was 20 minutes. The intensity of the shortwave diathermy was such that the subject felt a comfortable warm heat.

2. Ultrasound

The ultrasound unit was a Burdeck model UT-420A which operated at a frequency of 870 kilohertz. The coupling agent used was aquasonic gel®[9]. Intensity used was one watt per square centimeter. The current was continuous. The duration of treatment was five minutes. This intensity was chosen because it was within the therapeutic range of intensities used in a clinical setting.

3. Hot Pack

The hot pack used was a half size Tru-Moist Heat Pak (HP151), Tru-Eze Manufacturing Company, kept in a hydrocollator with a water temperature of 70 degrees Celsius plus or minus five degrees Celsius[7]. The dimensions of the hot pack were 12 by 30 centimeters. The hot pack was covered by two layers of terry cloth hot pack covers. The hot pack and its covers were placed for a 20 minute period crosswise over the upper forearm. In this manner, a 12 centimeter segment of the forearm was heated by the hot pack. This procedure was chosen because it complied with the standard procedure followed in physical therapy departments and clinics.

4. Needle Probe and Digital Thermometer

Subcutaneous temperature was monitored by a 24 guage needle probe Yellow Springs Instruments (YS1) No24. The needle probes were gas autoclaved by the Department of Surgical Supply at the University of Alberta Hospital prior to each testing.

Subcutaneous temperature changes were recorded by a digital thermometer Model 49TA Yellow Springs Instruments for the ultrasound and the hot pack treatments. A scanning Tele-Thermometer Model 47 Yellow Springs Instruments was used to record subcutaneous temperature changes associated with the shortwave diathermy treatment. The reason the two different thermometers were used was that the battery-operated Yellow Springs 49TA thermometer had been found to be unduly sensitive to electromagnetic influence, whereas the electrically-operated Yellow Springs 47 thermometer had not. Therefore, as the scanning Tele-Thermometer was less affected by the electromagnetic current of the shortwave diathermy, this thermometer was used for recording the subcutaneous tissue temperature during the shortwave diathermy treatment.

5. Electromyograph

Nerve conduction velocity testing was performed using a TECA TE-42 Electromyograph. Permanent recordings were taken on TECA photographic paper.

6. Timer

All treatments during the experiment were timed by a Gra-lab Timer, model 171.

CALIBRATION OF EQUIPMENT

All the apparatus was calibrated (see Appendix B for details). To insure optimal internal validity, the same Siemens 708 monode, Burdick UT-420A, hot pack, needle probes, digital thermometer, scanning thermometer, electromyograph, timer and skinfold caliper were used throughout the experimental procedure.

A representative of Electromed Services calibrated the output of the shortwave diathermy unit by using a calibration light test box. The intensity of the ultrasound unit was

calibrated by a Russian ultraschalleisthngsmessgerat N MY-3 unit. Calibration of the hot pack was done by repeated measurement of the temperature of the bath water in the hydrocollator. This calibration was done over a period of three days. The bath water temperature had to remain at 70 degrees Celsius plus or minus five degrees Celsius. The needle probes were connected to the same digital thermometer and the same scanning thermometer for calibration. The same digital thermometer was used in each of the ultrasound and hot pack treatments and the same scanning thermometer was used in each of the shortwave diathermy treatments. The two needle probes were calibrated against the same mercury thermometer and a temperature conversion scale for each needle probe to the chemical thermometer was made. All experimental procedures were timed by the same Gra-lab Timer. This procedure eliminated any discrepancies that may have existed between the timer on the shortwave machine and the ultrasound machine.

EXPERIMENTAL PROCEDURE

On arriving at the test laboratory, the subjects were given a full explanation of the testing procedures and then were asked to sign an Informed Consent Form (see Appendix A). Each subject was then assigned to one of the six treatment sequences as indicated in Table 2. There was a minimum of 48 hours between test procedures.

While standing, a triceps skinfold test was taken as described by Mayer[3]. In addition, a forearm skinfold test was taken in the following manner: once the proximal and distal stimulation points had been identified and marked, a point half-way between the two was marked and a skinfold thickness test was done at this site and recorded on the data sheet. The skinfold thickness test was taken with the crest of the skinfold in a longitudinal direction, parallel to the longitudinal axis of the forearm. Each subject was then asked to lie on a padded plinth and pillows were placed under their head and legs in order to make the subject comfortable. Their dominant arm was exposed from mid arm distally. The forearm and medial aspect of the hand was cleansed by rubbing it with isopropyl alcohol. The distal electromyographic electrode was placed over the muscle belly of abductor digiti minimi muscle and secured by tape. The ground electrode was placed on the tip of a finger. The stimulator was then placed over the ulnar nerve in the groove of the elbow. The position of the stimulator at which the greatest muscle action potential was seen on

the oscilliscope was marked with permanent ink. The course of the ulnar nerve was followed distally to where it emerged superficially in the mid forearm. The point of stimulation along the ulnar nerve at which the greatest muscle action potential was obtained (as detected on the oscilliscope) was marked with permanent ink. The distance between the proximal and distal stimulating sites was between 10-12 centimeters[9].

Figure 6

Equipment and Modalities Used in Experiment

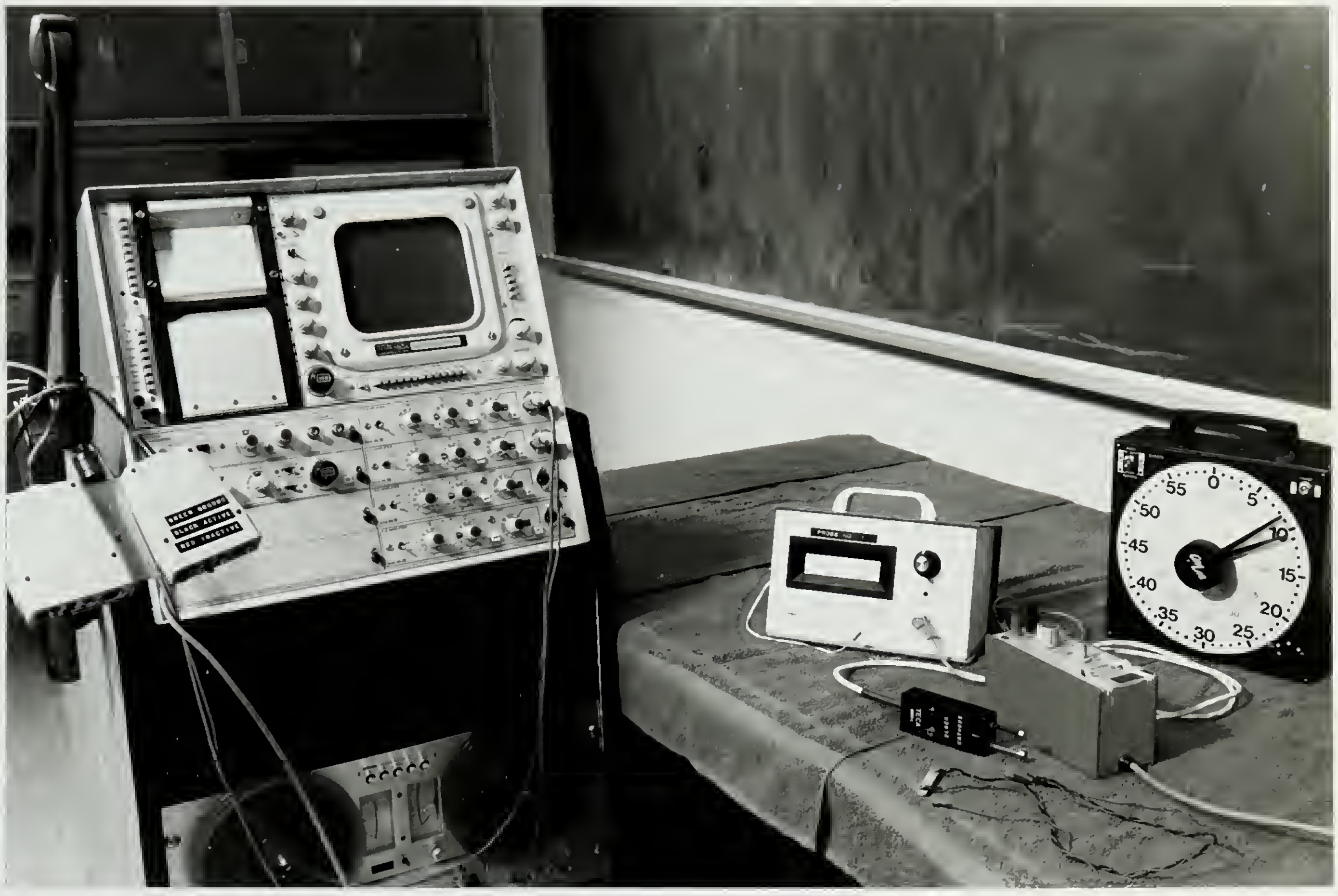

Figure 7

Electromyograph Timer, Digital Thermometer, Needle Probe, and Gra-lab Timer

The skin where the subcutaneous needle probe was to be inserted was cleansed by rubbing it with isopropyl alcohol. A subcutaneous needle probe was inserted by the experimenter to a length of approximately three centimeters diagonally into the subcutaneous tissue of the anteromedial aspect of the treatment arm half-way between the proximal and distal sites of stimulation[10]. The wire leading to the probe and the rubber tip of the probe was secured to the subject by tape in order to prevent pulling the probe out accidentally. The subject's temperature was allowed five minutes to stabilize. Stabilization was considered to have occurred when the subject's temperature had not fluctuated more than plus or minus 0.2 degrees Celsius over a period of one minute. Temperature recordings were taken at one minute pre-treatment, immediately prior to treatment (zero minute pre-treatment), and at one minute intervals during each of the treatments. Two other temperature recordings were taken: one immediately following the treatment (zero minute post-treatment), and the last recording was taken one minute after the end of the treatment procedure.

Immediately following the recording of the zero minute pre-treatment temperature, treatment was given in one of the following manners:

Shortwave diathermy

The application of shortwave diathermy followed the standard format used in a clinical setting.

A nine centimeter monode was placed three centimeters above the area to be treated. The monode was positioned (as stated previously) so that it was centered directly over the needle probe. The duration of the treatment was 20 minutes. The intensity was such that the subjects felt a comfortable warm heat. At the end of the treatment, the monode was removed and both the proximal and distal stimulation sites were wiped with dry gauze. This cleansing procedure was done in order to prevent any change in skin resistance that might have been caused by the accumulation of salt due to perspiration. Immediately after wiping the proximal and distal sites of stimulation, both the motor nerve conduction velocity and subcutaneous temperature were recorded. This procedure was repeated one minute later.

Ultrasound

The ultrasound intensity used was one watt per square centimeter with a frequency of 870 kilohertz applied for a duration of five minutes[6]. Aquasonic gel® served as the transmission medium. Overlapping circles at a rate of about two to three centimeters per second were used so that there was an even distribution of ultrasound energy. Full contact of the ultrasound head was maintained throughout treatment, in order to prevent loss of ultrasound energy[6]. Immediately following the end of the ultrasound treatment, the aquasonic gel® was removed at the proximal and distal sites of stimulation and a motor nerve conduction velocity test was completed and recorded as well as the subcutaneous temperature. The remaining aquasonic gel® was removed and a second motor nerve conduction velocity test and temperature were recorded one minute after the end of the treatment procedure.

Hot Pack

The hot pack was wrapped in two layers of terry cloth towelling and was applied to the anteromedial aspect of the forearm over the course of the ulnar nerve for a period of twenty minutes[6]. At the end of treatment, the hot pack was removed and both the proximal and distal stimulation sites were wiped clean with dry gauze. The cleansing procedure was done to prevent any change in skin resistance that might have been caused by the accumulation of salt due to perspiration. Immediately after wiping the proximal and distal sites of stimulation both the motor nerve conduction velocity and subcutaneous temperature were recorded. This procedure was repeated one minute later.

Motor Nerve Conduction Velocity

Motor nerve conduction velocity was tested by stimulating at both the proximal and distal points. A permanent record was taken of the supramaximal response by a foot control switch which took a picture of the electromyograph oscilliscope of fiber optic paper. Motor nerve conduction velocity data was collected at one minute pre-treatment, immediately prior to treatment, immediately following the end of the treatment, and one minute post-treatment.

Following the final temperature recording and motor nerve conduction velocity data recording, the needle probe was removed, the electrodes removed and the area cleaned.

Motor Nerve Conduction Velocity and Temperature Recordings

Four motor nerve conduction velocity recordings were taken. At one minute pre-treatment, zero minute pre-treatment, immediately at the end of treatment (zero minute post-treatment), and one minute after treatment ended. This same procedure was followed for temperature recordings. In addition to this, temperature recordings were made at one minute intervals during the five minute treatment of ultrasound and the twenty minute treatment of shortwave diathermy and hot pack.

STATISTICAL PROCEDURE

All statistical calculations were compiled by the University of Alberta Computing Services Statistical Application Analysis. Subcutaneous tissue temperature and motor nerve conduction velocity data were examined by a two by three way analysis of variance with repeated measurements over both factors[6]. A Neuman-Keuls multiple comparison of means was employed to compare selected means. The Pearson-Product Moment Correlation Coefficient was calculated for the one minute pre-treatment and the zero minute pre-treatment; and the zero minute post-treatment and the one minute post-treatment data for both subcutaneous tissue temperature and motor nerve conduction velocity. This calculation was done in order to test the examiner's reliability in testing motor nerve conduction velocity and to confirm that the subcutaneous tissue temperature had stabilized. The Pearson Product Moment Correlation Coefficient was calculated using all 18 subjects with three repeated measurements. The Pearson Product Moment Correlation Coefficient was also calculated for change in subcutaneous tissue temperature, change in motor nerve conduction velocity, and skinfold thickness layer for each modality taken separately.

Reliability Tests and Procedures

To ensure consistency in the experimental procedure, and maximize high internal validity, the following tests and procedures were performed (see appendix C for detailed description of each procedure).

1. Skinfold thickness test of the triceps and forearm.
2. Calculation of the motor nerve conduction velocity from the recordings made on the TECA photographic paper.

3. Control of experimentor's bias in calculation of the motor nerve conduction velocity.
4. The competency and safety of inserting a needle probe.

RISKS AND PRECAUTIONS

Burn is the most common potential risk to the subjects in the application of shortwave diathermy, ultrasound and hot packs. This risk factor was controlled and minimized by: 1) doing a skin sensation test to check the subject's discrimination between hot and cold; 2) wiping the skin dry of perspiration prior to the application of shortwave diathermy so as to prevent any point of concentration of the electromagnetic field on the skin; 3) by instructing the subject that they were to feel a comfortable, warm heat and NOTHING MORE. If they felt any discomfort whatsoever, they were to tell the experimenter and the machine would be turned off or the hot pack removed; 4) the subjects were under the constant supervision of the experimenter throughout the treatment procedure.

Contamination of the needle probe causing infection is a risk associated with the needle probe. This risk was controlled by having the needle probe gas autoclaved after each use. Further, the area of skin into which the needle has been inserted was first cleansed with isopropyl alcohol.

As the needle was inserted into an area where the ulnar nerve passes, there was a remote possibilty that the needle might contact the ulnar nerve. This unlikely occurrence was minimized by holding the needle diagonally to the forearm, picking up in a pinch-type grasp the skin and the subcutaneous tissue into which the needle probe is inserted, and pushing the needle probe in a slow, steady motion through the subcutaneous tissue. In this way, if the needle probe did hit the fascia covering the muscle the resistance was felt by the experimenter, and the experimenter did not insert the needle any further. If one was sure not to pierce the muscular fascia this provided sure protection to the ulnar nerve since it lies deep to muscle and its overlying fascia.

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D. CHAPTER IV - THE RESULTS

Eighteen healthy, informed volunteers (four males and 14 females) reporting no history of peripheral vascular disease, other disease, injury or medication known to cause neuropathies were examined. The age range was from 22 to 34 years (mean age 27.8 years). Only the dominant arm of each subject was tested. None of the subjects reported discomfort attributable to either the electrical stimulation technique or to the subcutaneous tissue temperature probe. Reliability tests for the measurement of the subcutaneous skinfold thickness; the measurement of the conduction velocity; and, the accuracy of electrode placement (as outlined in the appendix C) were completed by the author prior to data acquisition. The reliability and percent error tests indicated the author had a high reliability in performing the three above mentioned techniques (Table 4). The following statistical procedures were used in the analysis of the raw data:

The correlation between the one and zero minute pre-treatment subcutaneous tissue temperature was 0.9976, and the correlation between the zero and one minute post-treatment temperatures was 0.9975. The correlation between the one and the zero minute pre-treatment motor nerve conduction velocities was 0.8357, and the correlation between the zero and one minute post-treatment motor nerve conduction velocities was 0.8962 (Table 5). All correlation coefficients were statistically significant ($p < 0.01$).

The mean and standard deviation for the zero minute pre-treatment and the zero minutes post-treatment subcutaneous tissue temperature and motor nerve conduction velocities, for each modality, are given in Table 6. Table 7 illustrates the change (zero minute pre-treatment minus zero minute post-treatment) in subcutaneous tissue temperature and motor nerve conduction velocities associated with shortwave diathermy, ultrasound, and hot packs.

TABLE 4
Percent Error Tests for Measurement of Skinfold Thickness Layer, Measurement of Conduction Velocity, and Placement of Electrode

TEST PROCEDURE	PERCENT ERROR
Skinfold Thickness Layer	1.61%
Conduction Velocity	2.34%
Placement of Electrode	2.14%

TABLE 5
Correlation Coefficients for One and Zero Minute Pre-Treatment, and Zero and One Minute Post-Treatment on Subcutaneous Tissue Temperature and Motor Nerve Conduction Velocity

CRITERION MEASURE	ONE AND ZERO MINUTE PRE-TREATMENT	ZERO AND ONE MINUTE POST-TREATMENT
Subcutaneous Tissue Temperature	0.9976	0.9775
Motor Nerve Conduction Velocity	0.8357	0.8962

All values were statistically significant ($p < 0.01$).

TABLE 6
Mean and Standard Deviation of Zero Minute Pre- and Zero Minute Post-Treatment Subcutaneous Tissue Temperatures and Motor Nerve Conduction Velocities For Shortwave Diathermy, Ultrasound, and Hot Packs

	Subcutaneous Tissue Temperature (°C)		Motor Nerve Conduction Velocity (m/s)	
Modality	Zero Minute Pre-Treatment	Zero Minute Post-Treatment	Zero Minute Pre-Treatment	Zero Minute Post Treatment
Shortwave Diathermy	35.4 (1.2)	38.4 (1.4)	62.47 (4.50)	67.31 (5.48)
Ultrasound	35.4 (2.1)	35.1 (2.1)	64.12 (4.15)	63.52 (3.81)
Hot Packs	35.6 (2.4)	38.7 (2.0)	62.14 (4.82)	68.42 (7.13)

(Standard Deviation)

TABLE 7
Change in Subcutaneous Tissue Temperature and Motor Nerve Conduction Velocity Following The Application of Shortwave Diathermy, Ultrasound, and Hot Packs

Modality	Change In Temperature (°C)	Change In Motor Nerve Conduction (m/s)
Shortwave Diathermy	+2.9	+4.83
Ultrasound	-0.4	-0.60
Hot Packs	+3.0	+6.28

"+" denotes increase "-" denotes decrease

The analysis of variance tests demonstrated statistically significant time main effects and interaction effects for both dependent variables ($p < 0.001$). The treatment effect was statistically significant for temperature ($p < 0.001$), but was not statitically significant for motor nerve conduction velocity ($p < 0.05$). Tables 8 and 9 demonstrate the probability values obtained in the analysis of variance for both subcutaneous tissue temperature and motor nerve conduction velocity.

TABLE 8

Analysis of Variance for Subcutaneous Tissue Temperature

Source of Variation	Sum of Squares	Degree of Freedom	Mean Squares	F Ratio
Treatment Main Effects	77.906	2	38.953	8.642*
Treatment x Subjects Within Groups	153.250	34	4.507	
Time Main Effects	92.250	1	92.250	151.157*
Time x Subjects Within Groups	10.375	17	0.610	
Treatment x Time Interaction	65.953	2	32.977	34.499*
Treatment x Time x Subjects Within Groups	32.500	34	0.956	
Subjects Within Groups	168.938	17	9.938	

* Statistically significant at the $p < 0.001$ level

TABLE 9

Analysis of Variance for Motor Nerve Conduction Velocity

Source of Variation	Sum of Squares	Degrees of Freedom	Mean Squares	F Ratio
Treatment Main Effects	41.273	2	20.637	0.845
Treatment x Subjects Within Groups	830.063	34	24.414	
Time Main Effects	331.664	1	331.664	25.136*
Time x Subjects Within Groups	224.313	17	13.195	
Treatment x Time Interaction	236.742	2	118.371	9.968*
Treatment x Time x Subjects Within Groups	403.750	34	11.875	
Subjects Groups	1193.125	17	70.184	

* Statistically significant at the $p < 0.001$ level

The Newman-Keuls post hoc tests (Tables 10 and 11) demonstrated that there was no statistically significant difference between the pre-treatment means for the shortwave diathermy, ultrasound and hot pack groups for both subcutaneous tissue temperature and motor nerve conduction velocity. Post-treatment, there was a statistically significant

difference between the ultrasound mean and the means observed for both shortwave diathermy and hot packs for subcutaneous tissue temperature ($p < 0.01$). In comparing the post-treatment means of ultrasound, shortwave diathermy, and hot packs for motor nerve conduction velocity, there was a statistically significant difference between the ultrasound mean and the mean of shortwave diathermy at the $p < 0.05$ level and a statistically significant difference between the ultrasound mean and the hot pack mean at the $p < 0.01$ level. No statistically significant difference was observed between the post-treatment shortwave diathermy mean and that of the hot pack group for either subcutaneous tissue temperature or motor nerve conduction velocity.

A statistically significant difference between the pre- and post-treatment means was observed for shortwave diathermy and for hot pack on both subcutaneous tissue temperataure and motor nerve conduction velocity ($p < 0.01$). However, no statistically significant difference between the pre-treatment and post-treatment means for ultrasound for either of the dependent variables was observed.

In comparing the remaining combinations between pre- and post-treatment differences in means for motor nerve conduction velocity, the following were found to be statistically significant ($p < 0.05$): a) pre-treatment shortwave diathermy and post-treatment hot pack, b) pre-treatment ultrasound and post-treatment hot pack, c) pre-treatment hot pack and post-treatment shortwave diathermy. For subcutaneous tissue temperature, there was a statistically significant difference ($p < 0.05$) between the following: a) pre-treatment shortwave diathermy and post-treatment hot pack, b) pre-treatment ultrasound and both post-treatment shortwave diathermy and hot pack, c) pre-treatment hot pack and post-treatment shortwave.

The Pearson Product Correlation matrices for each separate modality indicated no statistically significant correlation between any combination of the three dependent variables (skinfold thickness, change in subcutaneous tissue temperature, and change in motor nerve conduction velocity), except that observed between the change in motor nerve conduction velocity and the change in subcutaneous tissue temperature associated with hot packs (Table 12).

TABLE 10
Newman-Keuls Test Probability Summary for Subcutaneous Tissue Temperature
(c^0)

	Post 0 US (35.10)	Pre 0 US (35.4)	Pre 0 SWD (35.44)	Pre 0 HP (35.62)	Post 0 SWD (38.32)	Post 0 HP (38.65)
+++ Post 0 US (35.10)	-	NS*	NS	NS	0.01**	0.01
Pre 0 US (35.4)	-	-	NS	NS	0.01	0.01
Pre 0 SWD (35.44)	-	-	-	NS	0.01	0.01
Pre 0 HP (35.62)	-	-	-	-	0.01	0.01
Post 0 SWD (38.32)	-	-	-	-	NS	NS
Post 0 HP (38.65)	-	-	-	-	-	-

*NS = statistically non-significant
** 0.01 = statistically significant at the $p \leq 0.01$ level

+++ For both Tables 10 and 11:
Post 0 US = 0 minute post-treatment ultrasound
Pre 0 US = 0 minute pre-treatment ultrasound
Pre 0 SWD = 0 minute pre-treatment shortwave diathermy
Pre 0 HP = 0 minute pre-treatment hot pack
Post 0 SWD = 0 minute post-treatment shortwave diathermy
Post 0 HP = 0 minute post-treatment hot pack

TABLE 11
Newman-Keuls Test Probability for
Motor Nerve Conduction Velocity (m/s)

.	Pre 0 HP (62.14)	Post 0 US (62.47)	Pre 0 SWD (63.52)	Pre 0 US (67.31)	Post 0 SWD (67.31)	Post 0 HP (68.42)
+++ Pre 0 HP (62.14)	-	NS*	NS	0.01**	0.01	0.01
Pre 0 SWD (62.47)	-	-	NS	NS	0.01	0.01
Post 0 US (63.52)	-	-	-	NS	0.05	0.01
Pre 0 US (64.12)	-	-	-	-	NS	0.01
Post 0 SWD (67.31)	-	-	-	-	-	NS
Post 0 HP (68.42)	-	-	-	-	-	-

*NS = statistically non-significant
** 0.01 = statistically significant at the $p \leq 0.01$ level

+++ See Table 10

TABLE 12
Correlation Matrices for Change in Subcutaneous Tissue Temperature, Change in Motor Nerve Conduction Velocity, and Skinfold Thickness for Each Modality

		Skinfold Thickness	Change In Tissue Temperature	Change In Motor Nerve Conduction
1.Shortwave Diathermy	Skinfold Thickness	1.00	-	
	Tissue Temperature	-0.1597	1.000	
	Motor Nerve Conduction	-0.2861	0.0709	1.000
2.Ultrasound	Skinfold Thickness	1.00	-	
	Tissue Temperature	0.0545	1.000	
	Motor Nerve Conduction	-0.2939	0.2888	1.000
3.Hot Pack	Skinfold Thickness	1.00	-	
	Tissue Temperature	0.412	1.000	
	Motor Nerve Conduction	0.2206	0.7256*	1.000

N=18 DF=16 (r @ 0.05=0.4863) (r @ 0.01=0.5897)

* Statistically significant at the 0.01 level.

E. CHAPTER V - DISCUSSION

Both subcutaneous tissue temperature and motor nerve conduction velocity increased significantly, and similarly, following the administration of shortwave diathermy and hot packs. For this reason, the increased conduction velocity is attributed to the heating effects of both modalities on motor nerves. These findings are in agreement with previous studies having used similar modalities and reporting an increase in motor nerve conduction velocity associated with an increase in subcutaneous tissue temperature.[1 3].

Ultrasound was observed to produce a small and a statistically non-significant decrease in both subcutaneous tissue temperature and motor nerve conduction velocity. This result is in general agreement with studies reported by Zankel[2], Farmer[4], and Madsen and Gersten[5]. These authors concluded that continuous ultrasound given at approximately one watt per square centimeter for five to ten minutes produced a decrease in motor nerve conduction velocity of the ulnar nerve[2 4 5]. However, the authors disagreed as to why this decrease occurred. Zankel[2] did not find a significant change in surface skin temperature, but did observe a statistically significant decrease in motor nerve conduction velocity after ten minutes of ultrasound over the ulnar nerve pathway in the forearm between the elbow and the wrist. Since he observed that ultrasound and cold packs both produced a decrease in ulnar motor nerve conduction velocity, the reduction in velocity was attributed to some factor other than the thermal effects of ultrasound. Zankel[2] suggested a micromassage action of the ultrasound might produce a change in the rate of exchange of transmembranal electrolytes, resulting in a decrease in motor nerve conduction velocity.

Farmer[4] did not measure temperature during testing but he did conclude that the mechanical effects of ultrasound overpowered the thermal effects at intensities of one, 1.5, and two watts per square centimeter. He postulated that it was the mechanical effects of ultrasound which produced a decrease in motor nerve conduction velocity. Farmer[4] suggested that the bipositive response of ultrasound enables clinicians to select dosages appropriate to their treatment objectives; i.e., dosages of 0.5 and 2.5 watts per square centimeter increased motor nerve conduction velocity while dosages of 1.0, 1.5 and 2.0 watts per square centimeter decreased motor nerve conduction velocity.

Madsen and Gersten[5] reported that intensities of 0.88 and 1.28 watts per square centimeter produced a decrease in ulnar motor nerve conduction velocity. This decrease in motor nerve conduction velocity was associated with a slight, but statistically non-significant, decrease in tissue temperature. The mechanism for this reduction was not discussed.

None of the previously reported studies discussed the possible cooling effects of the coupling medium used. It has been reported that Aquasonic gel® has a definite cooling effect on tissue temperature[6 7 11]. However, to what depth the cooling effect will take place was not discussed. This cooling effect was found consistently with each subject in the present experiment. In most subjects, application of the Aquasonic gel® resulted in an immediate decrease in the subcutaneous tissue temperature. Figure 8 illustrates the change in subcutaneous tissue temperature immediately prior to the application of the Aquasonic gel® , during the five minute ultrasound treatment, and immediately following the treatment. In the majority of the subjects, the post-treatment subcutaneous tissue temperature did not return to the original temperature that existed before the application of the Aquasonic gel® . The net overall loss in the subcutaneous tissue temperature was 0.2 degrees Celsius. It would appear that the heating effects of ultrasound at one watt per square centimeter for five minutes was not sufficient to counteract the cooling effect of the Aquasonic gel® .

It is suggested that the decrease in ulnar motor nerve conduction velocity associated with sonation might be attributable to the cooling effects of Aquasonic gel®. However, as both subcutaneous tissue temperature and motor nerve conduction velocity changes were statistically non-significant, this suggestion must be made with caution and requires further study to be substantiated.

Kramer[11], in his study on the mechanical and thermal effects of ultrasound, also found a cooling effect of the Aquasonic gel®. In his study, Kramer found a rapid fall of 2.6 degrees Celsius in subcutaneous tissue temperature during the first five minutes of pulsed and placebo ultrasound. This decrease in subcutaneous tissue temperature was associated with a decrease in motor nerve conduction velocity. Kramer attributed the decrease in motor nerve conduction velocity to the cooling effect of the Aquasonic gel® and not to the mechanical effects of ultrasound.

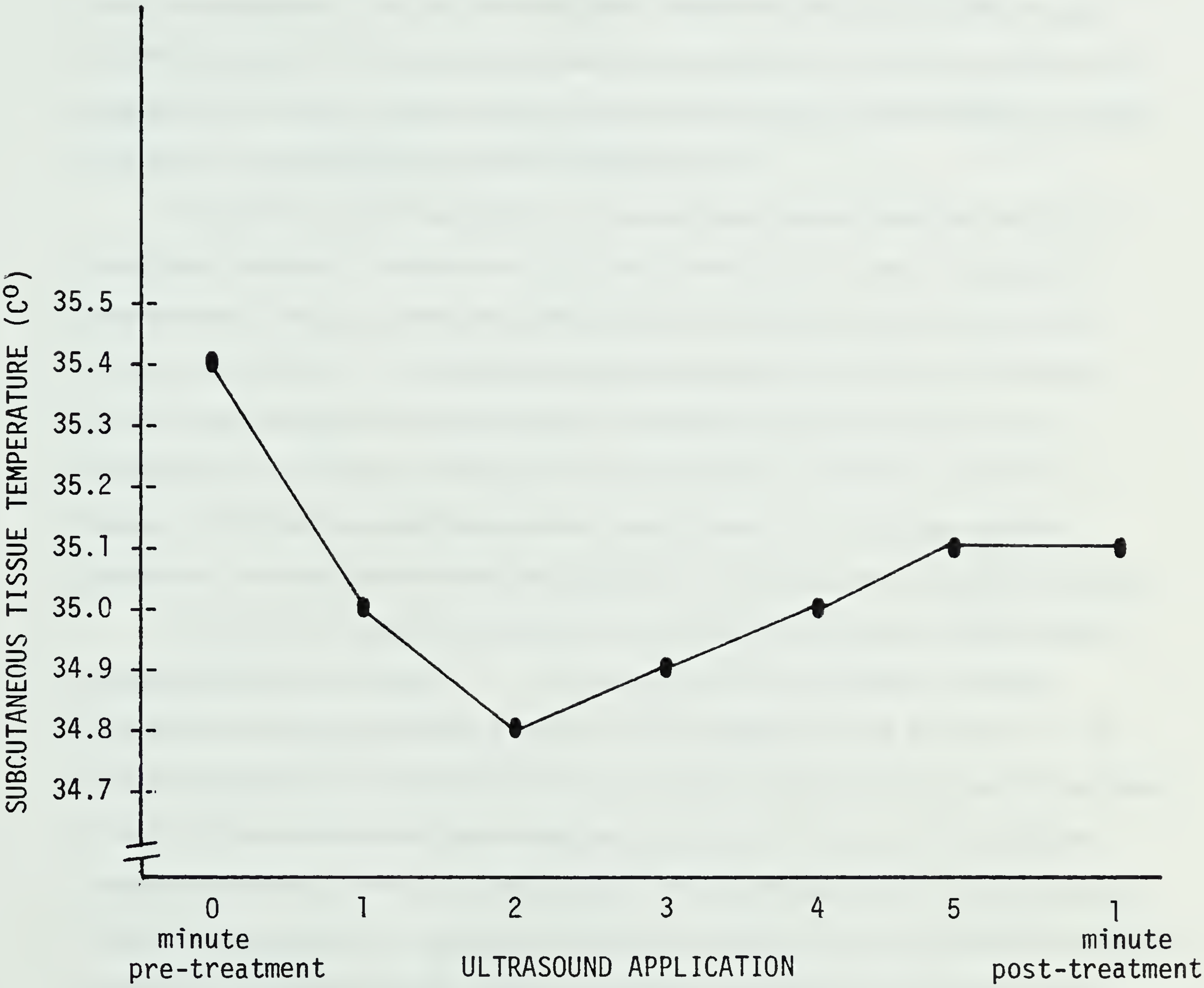

Figure 8

Change in Subcutaneous Tissue Temperature
During the Application of Ultrasound

The analysis of variance tests for both subcutaneous tissue temperature and motor nerve conduction velocity demonstrated a significant interaction effect over treatment and over time. There are a number of possible explanantions for this interaction, such as 1) the cooling effect of the Aquasonic gel® which could possibly counteract the heating effect of ultrasound; and 2) the selective heating effect of shortwave diathermy on metal. There is the possiblilty that the electromagnetic field of the shortwave diathermy was concentrated about the subcutaneous needle probe, resulting in selective heating of the needle and only a minor heating effect of tissue further away from the needle, as a result of a narrow concentration of the electromagnetic field.

According to Scott[8] and Lehmann[9], there will be minimum selective heating of a metal object situated in an electromagnetic field if the object is small. In the case of inductothermy, there is a minimum shunting effect if the metal object is placed in the center of the monode[8 9]. In the present experiment, placement of the inductothermy monode was centered over the subcutaneous needle probe by eyesight only. It is possible that some selective heating of the needle probe took place in some of the subjects. This heating would have been minimal, however, as no subject reported discomfort from the needle during the application of the shortwave diathermy treatment.

It has been documented that shortwave diathermy and hot packs predominantly heat subcutaneous fatty tissue[6 8 9 10]. Ultrasound has a high permeability through subcutaneous fat tissue and therefore has a minor heating effect on fat tissue[9 10]. The relationship between: a) skinfold thickness and change in subcutaneous tissue temperature, b) skinfold thickness and change in motor nerve conduction velocity, and c) change in subcutaneous tissue temperature and change in motor nerve conduction velocity, when using shortwave diathermy, ultrasound or hot packs have not been reported in the available literature. In the present study, the only statistically significant correlation was that between the change in subcutaneous tissue temperature and change in motor nerve conduction velocity associated with hot packs. There are a number of possible explanantions for this finding other than the possibility that no meaningful correlation exists. Firstly, all the subjects in the present study were well below the 80 percentile range of minimum triceps skinfold thickness indicating obesity as illustrated in Table 13. It is suggested that the skinfold thickness layer of the forearm was too small to be an

important factor in absorbing heat produced by the shortwave diathermy and ultrasound.

TABLE 13

Comparison of Mayer's Standard of Minimum Triceps Skinfold Thickness Indicating Obesity and Triceps Skinfold Thickness Of Subjects (millimeters)

AGE (YEARS)	MAYER'S STANDARD FOR MALES	MALE SUBJECTS	MAYER'S STANDARD FOR FEMALES	FEMALE SUBJECTS
22	18	7.12*	28	26.1*
23	18	-	28	26.9*
24	19	-	28	15.74*
25	20	5.79*	29	14.1*
26	20	-	29	20.1*
27	21	-	29	22.9*
28	22	-	29	
29	22	-	29	17.1*
30-50	23	13.49**	30	17.7***

- no subjects in that age group
* one subject in that age group
** mean of two subjects in that age group
*** mean of six subjects in that age group

Adapated from: Mayer J: Overweight: Causes, Costs and Control. Prentice-Hall, Inc. Enlgewood Cliffs, New Jersey, 1968.

Secondly, the selective heating effects of shortwave diathermy on the subcutaneous needle probe may have affected the relationship between the change in subcutaneous tissue temperature and the change in motor nerve conduction velocity. Thirdly, in the case of ultrasound, the cooling effect of the Aquasonic gel® may have counteracted the heating effect of ultrasound and therefore masked the relationship between change in subcutaneous tissue temperature and change in motor nerve conduction velocity.

From the results of the statistical analysis of the data of this study, it is impossible to draw any firm conclusions about the relationship between the change in subcutaneous tissue temperature, the change in motor nerve conduction velocity, and the skinfold thickness layer. It does not seem likely that the subcutaneous tissue layer is an important factor in the subcutaneous tissue temperature nor the change in motor nerve conduction velocity.

Woodbury[14] stated that both the physical properties and fiber geometry help to determine the conduction speed of nerves. He stated the most important factor is the extent of the depolarization induced by an increase in sodium permeability. The greater the sodium permeability is, the greater the sodium influx will be resulting in an increase in the rate of rise of the action potential. This increase in the rate of rise of the sodium input current will increase the flow of the local circuit currents and results in a quicker excitation of adjacent regions of the nerve fiber and, thus, increase nerve conduction velocity.

A reduction in the degree of depolarization of the nerve fiber to reach the threshold of the action potential also increases nerve conduction velocity. A reduction in threhold means that less sodium input current is needed for depolarization and, therefore, there is less movement of sodium ions resulting in an increase in nerve conduction velocity[14].

A smaller capacity of charge on the nerve fiber membrane decreases nerve conduction velocity. This smaller capacity of charge on the nerve fiber decreases the length of time the local circuit currents must flow to depolarize the nerve fiber membrane[14]. Increase in the concentration of mobile ions in both the interstitial fluid and intracellular plasm results in an increase in nerve conduction velocity. This increase in concentration increases the local circuit flow of sodium influx and potassium efflux and,

therefore, increases nerve conduction velocity.

Furthermore, in myelinated fibers, conduction velocity is dependent on the thickness of the myelin sheath relative to the axon diameter and on the distance between nodes. Conduction speed has a linear relationship with the diameter of the myelinated fiber[14].

From the review of the literature and from what Woodbury's comments on the effect of heat on nerve conduction, the author would like to propose the following possibilities as answers to the question of how heat causes an increase in nerve conduction in the studies described in this thesis. It seems possible that the increase in heat caused by shortwave diathermy and hot packs could have resulted in an increase in the sodium permeability of the nerve fibers within the ulnar nerve and/or an increase in the flow of the local circuit currents, and/or a decrease in the resting membrane potential. Other possibilities are: an increase in temperature might have resulted in an increase in the agitation of the sodium and potassium ions around the nerve membrane and thus promote the influx and efflux of sodium and potassium through the membrane. A decrease in the viscosity of the nerve fiber cytoplasm would also facilitate the ionic current flow.

As stated previously, the author believes that the decrease in subcutaneous tissue temperature and motor nerve conduction velocity associated with ultrasound was caused by the cooling effect of the Aquasonic gel®. The cooling effects of the Aquasonic gel® may have produced a slowing of the efflux of postassium which would then delay the recovery of the nerve fiber back to its resting state.

In summary, it seems that the increase in temperature brought about by shortwave diathermy and hot packs might have had an effect on each part of the sequences that makes up an action potential. The decrease in temperature brought about by the cooling effect of the Aquasonic gel® used with the application of ultrasound might have had an effect on the mechanism of recovery of the nerve fiber back to its resting state.

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F. CHAPTER VI - CONCLUSION

The purpose of this study was to examine the effects of shortwave diathermy, ultrasound and hot packs to the subcutaneous tissue temperature and the motor nerve conduction velocity of the ulnar nerve. A sample of 18 informed adults was used, only the dominant arm of each subject was tested. Each subject was tested three different times, once for each modality.

The testing procedure involved taking two pre-treatment tests of subcutaneous tissue temeperature and motor nerve conduction velocity, applying the modality appropriate for that particular session and, at the end of the treatment, two more tests on subcutaneous tissue temperature and motor nerve conduction velocity. On their first visit to the experimental laboratory, a skinfold thickness measurement of the triceps and the forearm was taken on each subject.

The data was analyzed by a two by three analysis of variance with repeated measurement. A Newman-Keuls tests was performed to analyze the differences between the cell means. A Pearson Product Correlation Coefficient was performed to investigate whether there was a correlation between the change in the subcutaneous tissue temperature, and the change in motor nerve conduction velocity and the skinfold thickness layer for each modality.

Results indicated that shortwave diathermy and hot packs produced a statistically significant increase in both subcutaneous tissue temperature and motor nerve conduction velocity, whereas ultrasound did not significantly change subcutaneous tissue temperature nor motor nerve conduction velocity. The Pearson Product Correlation Coefficient demonstrated a statistically significant correlation between the change in subcutaneous tissue temperature and the change in motor nerve conduction velocity with hot packs only. There was no significant correlation between the skinfold thickness layer or the change in subcutaneous tissue temperature or the change in motor nerve conduction velocity for any of the three modalities.

Therefore, in conclusion, within the restrictions of this study, it may be stated that shortwave diathermy and hot packs produce a statistically significant increase in subcutaneous tissue temperature and motor nerve conduction velocity of the ulnar nerve, whereas ultrasound does not. The increase in motor nerve conduction velocity of the

ulnar nerve is attribuatable to the heating effect caused by shortwave diathermy and hot packs.

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H. APPENDIX A - FORMS USED IN RESEARCH PROJECT

QUESTIONNAIRE FOR SCREENING POTENTIAL SUBJECTS

TO: **Potential** subjects who have agreed to participate in this study to examine the effects of shortwave diathermy, ultrasound, and hot packs on motor nerve conduction velocity.

FROM: Yvette D Claveau

In order that the results of this study be as valid as possible, please complete the details below. I assure you that confidentiality shall be strictly maintained.

PERSONAL DATA FORM

NAME: ______________________________

ADDRESS: __________________________

PHONE NUMBER: _________________________

AGE: _______ YEARS _________MONTH

WEIGHT: ____________ kilograms HEIGHT: ____________ centimeters

TRICEPS SKINFOLD THICKNESS TEST: ______________

FOREARM SKINFOLD THICKNESS TEST: ______________

PLEASE TURN PAGE AND COMPLETE THE SECOND PORTION OF THIS QUESTIONNAIRE

Please indicate by placing a check in the appropriate column whether you have had any of the following medical problems:

	YES	NO
-Diabetes		
-Metal implant		
-Disease of the nervous system		
-History of vascular disease		
-History of damage to the ulnar nerve		
-Previous injury of elbow (fracture, dislocation)		
-Loss of sensation in the forearm and hand		
-Lead Poisoning		

DATE: __________ SIGNED: ______________

INFORMED CONSENT FORM FOR EXPERIMENT

Effects of Shortwave diathermy, ultrasound, and hot pack on motor nerve conduction velocity.

I (*print name*) ______________________ do hereby agree to participate in this research study on the effects of shortwave diathermy, ultrasound, and hot packs on motor nerve conduction velocity. I have been given a full explanation of the procedure, the risks and the scientific benefit. I have been advised that I may withdraw from the experiement at any time I so choose.

DATE: ______ SUBJECT'S SIGNATURE:__________________

I hereby certify that I have given to the above person an explanation of the experimental procedure, its risks and benefits.

PRINICPAL INVESTIGATOR: _______________

I hereby certify that I was a witness to the above explanation and signatures.

DATE: ______ WITNESS: ______________________

INFORMATION TO POTENTIAL SUBJECTS

Shortwave diathermy, ultrasound, and hot packs are commonly used modalities in physical therapy treatments. The purpose of this study is to compare the heating effect of these modalities on the conduction velocity of the ulnar nerve.

There will be three treatment sessions, each of approximately forty minutes. There must be at least 48 hours between each treatment session. Each treatment will be applied within the normal therapeutic procedures.

In the shortwave diathermy treatment, you will have a monode placed over your forearm near the elbow. During the treatment you are to feel a comforting warm heat.

In the ultrasound treatment, a coupling agent (gel) will be applied to your forearm. You will then receive a five minute treatment of ultrasound. The ultrasound head is moved over the treatment area in a slow, circular manner. You will feel warmth from the ultrasound.

In the hot pack group, you will have a hot pack covered in a terry cloth placed on your forearm for twenty minutes. You will feel a gentle warmth from the hot pack during this time.

If, during any of the three treatments, you feel the shortwave diathermy, ultrasound or hot pack is getting too warm, you are to tell the experimenter and the treatment will be stopped.

The following procedures will be carried out at each session:

On arrival at the laboratory, a skinfold thickness measurement will be taken of your forearm and arm. Your hand and arm will be cleansed with ispropyl alcohol. Electrodes will be taped on your hand and a ground electrode on a finger. Two points of stimulation will be marked on your arm. A needle probe will be inserted diagonally into the treatment area of your forearm. You are given five minutes rest for temperature stabilization. Once your temperature is stabilized, the first pre-test motor nerve conduction velocity will be taken. This test will be repeated one minute later and the treatment to which you have been assigned for that particular visit administered in accordance with the above description. Following treatment, two more motor nerve conduction velocities will be taken at one minute intervals. All electrodes and the needle probe will then be removed, your forearm wiped clean and you may leave.

You are free to ask the investigator any questions. You are free to withdraw from the experiment any time you choose.

All identification and personal information will be kept strictly confidential.

Thank you for your support in this study.

I. APPENDIX B - CALIBRATION OF EQUIPMENT

Calibration of the Shortwave Diathermy Unit

The calibration of the output of the Siemens 708 shortwave diathermy unit was done in the following manner. This procedure was performed by a technical representative of Electromed Services [2]. A calibration light test box from ENRAF NONIUS DELEFT Manufacturing Company was used. The monode was centered on the side of the light box labelled monde circuplode. The shortwave diathermy machine was turned on and the intensity was turned on as high as possible (i.e., 5 on the Siemens 708 model). Once the shortwave diathermy machine was in tune with the light box, the photo detector on the light box was read. As the photo detector reads out in direct current milliamperes this was then converted into watts by the use of the conversion table provided. The watts indicated by the conversion table were compared to the watts output indicated on the Siemens 708 and, if the two wattages were the same, the machine was considered calibrated. If not, adjustments were made to make the two wattages the same.

Calibration of the Ultrasound Unit

Calibration of the intensity of the Burdick UT 4300 Ultrasound Machine was carried out in the following manner by the experimenter with the use of the Russian Ultraschalleistungsmessgerat N MY-3 unit. The water container of the Russian N MY-3 unit was filled to the water mark with distilled water. The ultrasound head was covered on its outer circumference by foam padding so that the ultrasound head fitted snugly into the opening provided for the ultrasound head found on top of the water container. The ultrasound head was parallel to the water line mark. The watt indicator was set at six watts total output (equal to one watt per square centimeter). The ARR switch was pushed down so as to release the metal plate. The ultrasound machine was turned on to an intensity of one watt per square centimeter. If the intensity output of the ultrasound machine was accurate, the red indicator corresponded exactly with the vertical line on the upper surface of the watt indicator. If the intensity was not accurate, the red indicator was off the vertical line. Adjustment of the intensity output was then made on the ultrasound machine by turning the dial on the underside of the machine until the red indicator and the vertical line and the wattage output indicated on the ultrasound machine all

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[2]Electromed Services
7913 Argyll Road
Edmonton, Alberta

corresponded to one watt per square centimeter.

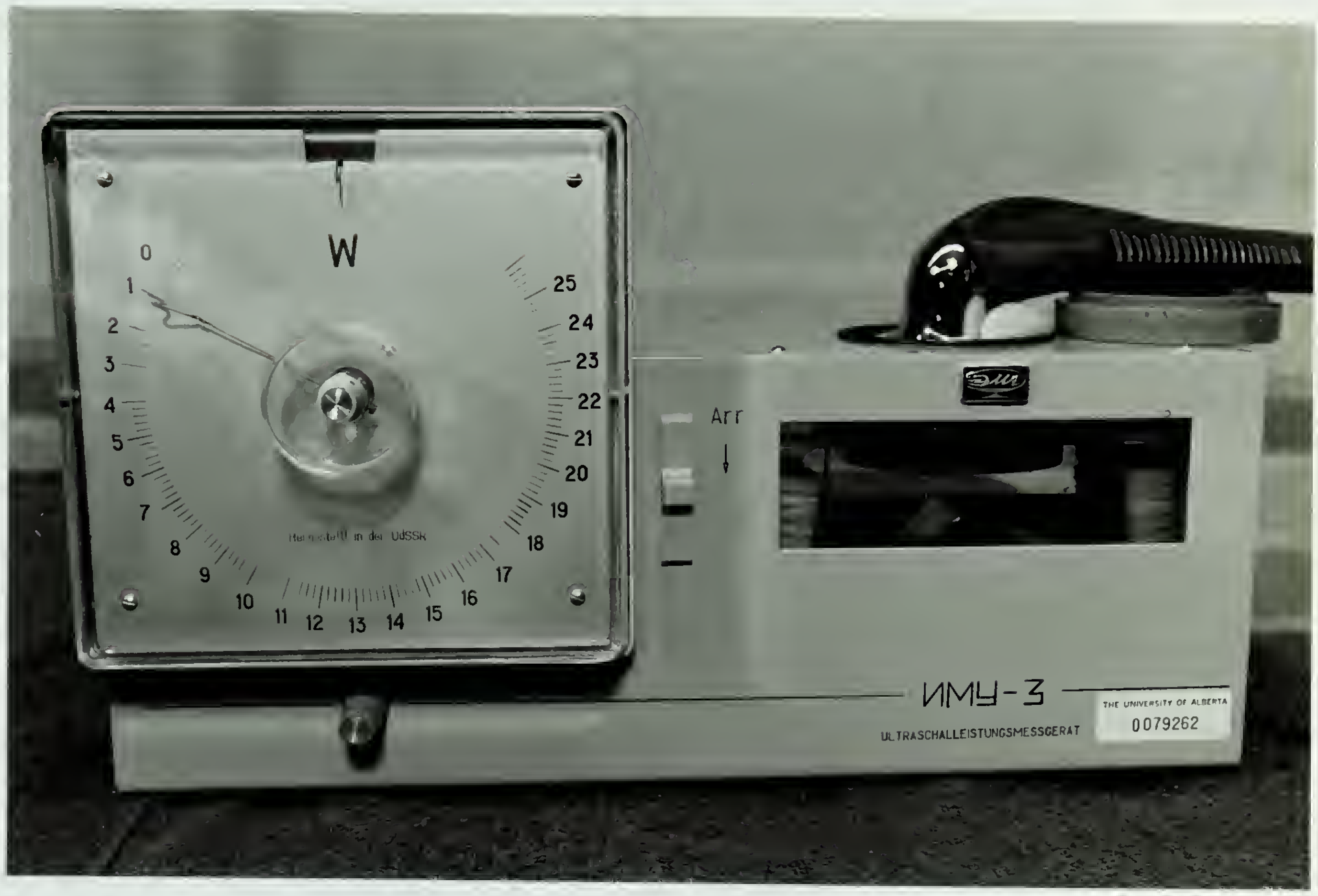

Figure 9

Russian Ultrachallersdungomessgerat N MY-3 Unit with Burdick Ultrasound Unit

Calibration of the Hot Pack

The same hot pack was used throughout the experiment. The water temperature of the hydrocollator from which the hot pack was removed was tested prior to each use of the hot pack. Unless the water temperature was between 70 degrees Celsius, plus or minus five degrees Celsius, the hot pack was not used. To insure that no one else used the hot pack, a message was taped to the hydrocollator requesting all persons not to use that particular hot pack.

Calibration of the Needle Probe, Digital Thermometer and Scanning Thermometer

A Fisher Oven of 0.7 cubic feet and a Propper Chemical Thermometer (temperature range of 10 to 200 degrees Celsius) was used for the calibration of the two needle probes and the two thermometers. Calibration was done as follows. The needle probe was taped to the chemical thermometer so that the tip of the needle probe was close to, but not touching, the bulb of the chemical thermometer. The two were inserted into the middle hole of the Fisher oven and secured in place with tape (the two remaining holes on the oven were blocked with cork). The needle probe was connected to the digital thermometer and the oven was turned on. Once the Fisher oven had heated the chemical thermometer and the needle probe to slightly above 43 degrees Celsius (the highest temperature the digital thermometer will record), the oven was turned off and the chemical thermometer and needle probe were allowed to cool. Once the digital thermometer recorded 43 degrees Celsius, the temperature on the chemical thermometer was recorded. Thereafter, as the temperature on the chemical thermometer decreased every .5 degrees Celsius, the corresponding temperature on the digital thermometer was recorded. This process continued until the chemical thermometer had reached 27.5 degrees Celsius, well below any temperature expected to occur during the experimental procedure. This same procedure was repeated with the scanning thermometer. The highest temperature that the scanning thermometer recorded is 50 degrees Celsius and, therefore, the oven was turned off once the temperature has reached 50 degrees Celsius. The procedure of temperature recording during the cooling of the chemical thermometer and needle probe was the same procedure as that used with the digital thermometer (see pages 73 to 76).

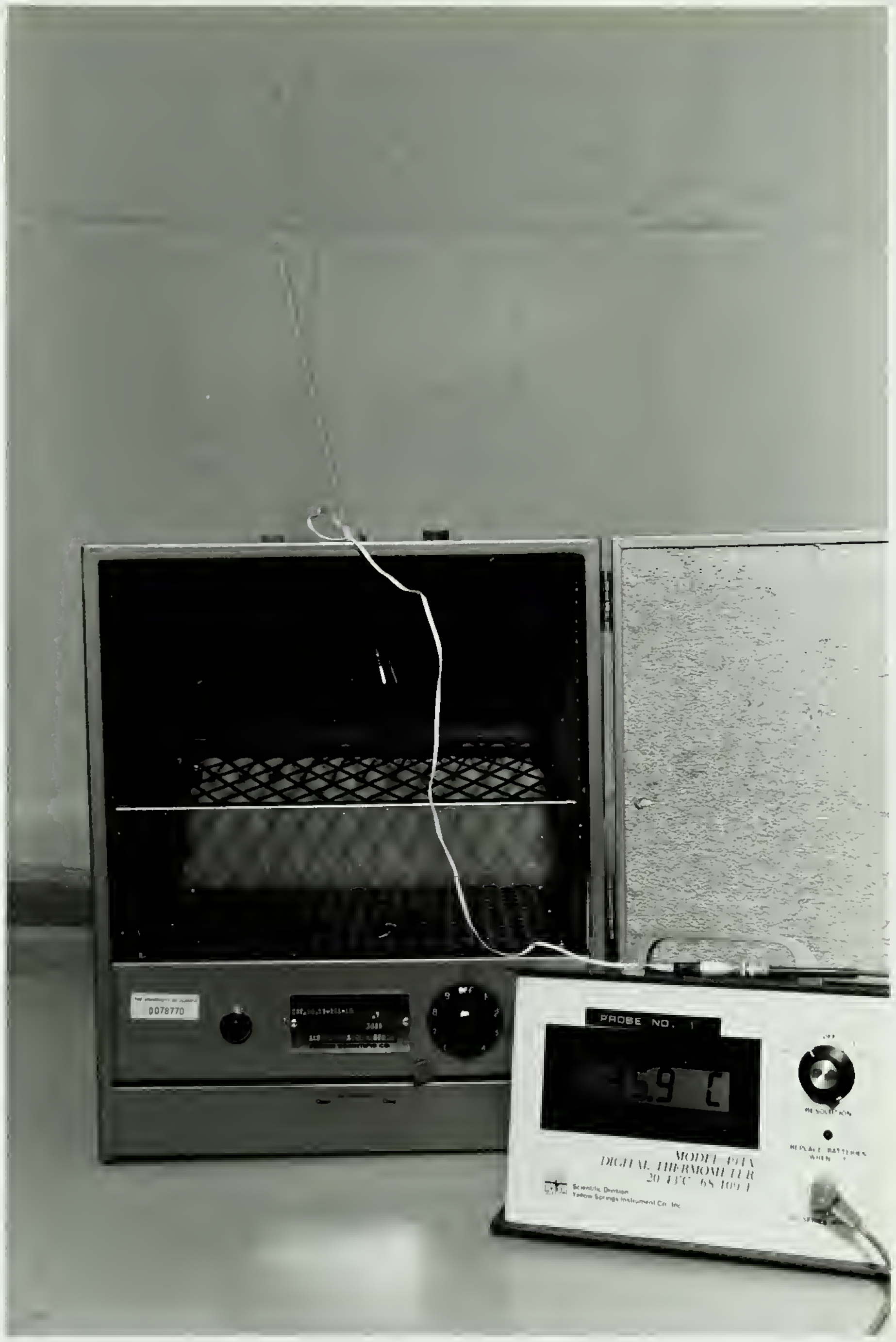

Figure 10

Calibration of a Needle Probe

With the Digital Thermometer

NEEDLE PROBE #1 -- DIGITAL THERMOMETER #1

Temperature - Chemical Thermometer	Temperature - Digital Thermometer
44.0	42.9
43.5	42.4
42.5	41.6
42.0	41.5
41.5	41.0
41.0	40.8
40.5	40.3
40.0	40.0
39.5	39.7
39.0	39.3
38.5	38.8
38.0	38.9
37.5	38.2
37.0	38.1
36.5	37.6
36.0	37.2
35.5	36.6
35.0	36.5
34.5	36.1
34.0	35.8
33.5	35.5
33.0	35.2
32.5	34.8
32.0	34.6
31.5	34.2
31.0	34.0
30.5	33.6
30.0	33.4
29.5	33.0
29.0	32.8
28.5	32.6
28.0	32.2
27.5	31.8
27.0	31.5

NEEDLE PROBE #3 -- DIGITAL THERMOMETER #1

Temperature - Chemical Thermometer	Temperature - Digital Thermometer
39.5	43
39.0	42.7
38.5	42.6
38.0	42.5
37.5	42.1
37.0	41.9
36.5	41.6
36.0	41.4
35.5	41.1
35.0	40.5
34.5	39.8
34.0	39.1
33.5	38.9
33.0	38.6
32.5	38.4
32.0	38.0
31.5	37.6
31.0	37.1
30.5	36.8
30.0	36.2
29.5	35.9
29.0	35.3
28.5	34.9
28.0	34.3
27.5	33.8
27.0	33.2

NEEDLE PROBE #1 ---- SCANNING THERMOMETER

Temperature - Chemical Thermometer	Temperature Scanning Tele Thermometer
50.0	49.1
49.5	49.0
49.0	48.5
48.5	48
48.0	47.0
47.5	47.5
47.0	46.2
46.5	46.0
46.0	45.5
45.5	45.2
45.0	45.0
44.5	44.9
44	44
43.5	44.0
43.0	43.5
42.5	43.0
42.0	42.5
41.5	42.3
41.0	42.0
40.5	41.9
40.0	41.5
39.5	40.9
39.0	40.7
38.5	40.3
38.0	39.9
37.5	39.5
37.0	39.2
36.5	38.9
36.0	38.7
35.5	38.1
35.0	37.9
34.5	37.3
34.0	36.9
33.5	36.5
33.0	35.9
32.5	35.3
32.0	34.9
31.5	34.5
31.0	34.3
30.5	34.0
30.0	33.8
29.5	33.1
29.0	33.0
28.5	32.8
28.0	32.5
27.5	32.0
27.0	29.7

NEEDLE PROBE #3 ----- SCANNING THERMOMETER

Temperature - Chemical Thermometer	Temperature Scanning Tele Thermometer
50.0	above scale
49.5	"
49.0	"
48.5	"
48.0	"
47.5	"
47	50
46.5	49.2
46.0	49.8
48.5	45.2
45.0	48.0
44.5	47.8
44.0	47.2
43.5	47.0
43.0	46.5
42.5	46.3
42.0	46.0
41.5	45.5
41.0	45.1
40.5	44.9
40.0	44.6
39.5	43.8
39.0	43.1
38.5	42.4
38.0	42.0
37.5	41.3
37.0	40.9
36.5	40.4
36.0	40.2
35.5	40.1
35.0	39.9
34.5	39.0
34.0	38.8
33.5	38.4
33.0	38.1
32.5	37.5
32.0	37.2
31.5	36.7
31.0	36.3
30.5	36.1
3.00	35.7
29.5	35.2
29.0	35.0
28.5	34.9
28.0	34.6
27.5	34.1
27.0	39.9

J. APPENDIX C - RELIABILITY TESTS AND PROCEDURES

1. Test of percent error of skinfold thickness measurement of triceps and forearm

The reliability of the experimenter in accurately measuring the skinfold thickness of the triceps and the forearm was tested in the following manner. The subject was repeatedly tested ten times for triceps and forearm skinfold thickness. A percent error test was then done for both the triceps and the forearm measurements. The procedure was as follows on each measurement. The subject was standing with the arm to be tested hanging relaxed by his/her side. For the measurement of the triceps skinfold thickness, a level halfway between the lateral tip of the acromion process and the proximal tip of the olecronon was marked. A pinch grasp of the subcutaneous tissue was taken at about one centimeter above the mark. The crest of the skinfold was parallel to the long axis of the arm. The caliper jaws were applied to the exact site where the skin was marked. The spring handles were released fully and when the pointer on the dial had steadied, a readoff of the measurement in tenths of millimeters was taken.

For the measurement of the forearm skinfold thickness, the subjects abducted their arm slightly so as to facilitate measurement. A level six centimeters distal to the medial epicondyle was marked on the medial border of the forearm. A pinch grasp of the subcutaneous tissue was taken about one centimeter above the mark. The crest of the skinfold was parallel to the forearm. The caliper jaws were applied to the exact site where the skin was marked. The spring handles were released fully and when the pointer on the dial had steadied, a readoff of the measurement in tenths of millimeters was taken. A percent error was then calculated on the ten repeated measurements of both the triceps and the forearm skinfold thickness.

2. Test of Percent Error of Calculation of Motor Nerve Conduction Velocity

The reliability of the experimenter in accurately calculating the motor nerve conduction velocity was tested in the following manner. Two sites of stimulation were marked on the forearm of a subject. Ten recordings of supramaximal stimulation of each site was recorded on TECA photographic paper. These 20 recordings were then coded and shuffled. All the horizontal lines (parallel to the base line of the action potential) and the vertical lines (drawn from the point of upward deflection perpendicular to the horizontal line) were drawn on the photographic paper first. Once this procedure had been completed on all the 20 recordings, the motor nerve conduction velocity was then

calculated for each recording. A test of percent error was then done on the repeated measurements of the 20 recordings of motor nerve conduction velocity. A code was made by the experimenter so as to match the identical recordings. Each of the recordings was calculated on two separate traits and then a reliability test was done. Furthermore, the identical recordings were then matched and another reliability test was done on these recordings.

3. Control of Experimenter's Bias in Calculation of Motor Nerve Conduction Velocity

In order to control for experimenter's bias in measurement of the motor nerve conduction velocity, the following procedure was used. The one minute pre-treatment, zero minute pre-treatment, zero minute post-treatment, one minute post-treatment recordings of motor nerve conduction velocity were coded, cut out and attached randomly onto a separate page. The experimenter was then able to calculate the motor nerve conduction velocity without knowing if that particular recording was a pre- or post-treatment recording.

4. Needle Probe Insertion

The competency of the experimenter in inserting a needle probe accurately and safely was evaluated by Dr. Anne Bellamy. See attached letter.

university of Alberta hospitals

8440 - 112 Street
Edmonton, Alberta
Canada T6G 2B7
(403) 432-8822

June 24,1983.

TO WHOM IT MAY CONCERN:

Re: Yvette CLAVEAU

This letter is to certify that in my opinion Yvette Claveau has obtained the necessary expertise required to insert the subcutaneous needle for measuring temperature as required by her current research proposal. I have observed her technique in this needle insertion and I have no hesitation whatsoever in recommending that she be allowed to carry this out as part of her research study. If you require further information do not hesitate to contact me.

Sincerely,

LABellamy

/paa

L.A.Bellamy,M.D.,FRCP(C)

University of Alberta Hospital

Walter C. Mackenzie Health Sciences Centre

Aberhart Centre

Mewburn Veterans Centre

University Hospitals Hostel

University Hospitals Industrial Services Centre

K. APPENDIX D - RAW DATA COLLECTION FORMS

NAME:

DATE: TIME:

ROOM TEMPERATURE:

TREATMENT: SWD US HP

PROBE USED:

TRICEPS SKINFOLD THICKNESS:

FOREARM SKINFOLD THICKNESS:

SENSATION TEST HOT vs. COLD

DATA COLLECTION

	TEMPERATURE		MOTOR NERVE
	Probe	Converted	CONDUCTION VELOCITY
1 minute pre-treatment			
0 minutes pre-treatment			
During treatment:			
1 minute			
2 minutes			
3 minutes			
4 minutes			
5 minutes			
6 minutes			
7 minutes			
8 minutes			
9 minutes			
10 minutes			
11 minutes			
12 minutes			
13 minutes			
14 minutes			
15 minutes			
16 minutes			
17 minutes			
18 minutes			
19 minutes			
20 minutes			
0 minutes post-treatment post-treatment			
1 minute post-treatment			